Sky and TELESCOPE

Northern lights at Goose Bay

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Vol. XIII, No. 2

DECEMBER, 1953

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A Start in Eclipse Planning

THREE OF US are planning a trip into the path of totality of the June 30, 1954, solar eclipse. In making preliminary arrangements, we have collected a considerable amount of information that may be helpful to others and save them unnecessary work.

To approach the question of where to go, we first secured a copy of **Total Eclipse of the Sun, June 30, 1954**, supplement to the 1954 **American Ephemeris**, from the Superintendent of Documents, Washington 25, D. C., for 40 cents. This has a good map in it of the eclipse path and also a table of co-ordinates of the center line and the northern and southern limits of the path of totality, among other things. From the table, we plotted the path on a National Geographic map of Alaska, Canada, and Greenland. This gave us a good idea as to where the eclipse path was with respect to home.

Information on the area the path crossed was then required. Several coupons were clipped from the travel advertisements in last summer's newspapers. This was a shotgun type of approach but it did get some results. One was the official road map of Ontario (published by the Department of Highways, Ontario, Parliament Buildings, Toronto 2, Ont.), an excellent road map with a scale of about 24 miles per inch. Unlike many other road maps, it shows latitude and longitude lines, so that it was possible to plot the eclipse path on it. We had road maps for the states involved, too.

Since we had decided to drive, we had to stick to the roads or perhaps take a train the last part of the way. In northern Ontario there is but one highway, Route 11, which crosses the center of the path of totality between Hearst and Kapuskasing. The Ontario Northland Railroad also goes a considerable distance along the path of totality farther north than the highway. It is inside the limits of totality from south of Fraserdale to the end of the line at Moosonee on James Bay, a distance of 120 miles or so. Fraserdale is about 550 miles from Toronto on the railroad. Between June 17 and September 12, 1953, two trains were scheduled each way each week between Cochrane and Moosonee. The Ontario Northland offices are at North Bay, Ontario, if further information is desired.

Because of the transportation problem, our plans became centered on the Hearst-Kapuskasing area. This is on the highway and far enough north and east along the path from the beginning of the eclipse that the sun will be 13° or so above the horizon. The railroad is farther north and east, but the sun there will be only two degrees higher, and we decided the difference was not worth the trouble of packing equipment for train transportation or combination of automobile and train travel.

For more details of the area, topographic maps of Ontario were secured from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa, Ont. These maps cost 25 cents (Canadian) per sheet and the index sheet is 25 cents. The 42-SE Hearst-Cochrane map with a scale of eight miles per inch is the only one available on a large scale for that area. The 42-SW Geraldton-White River map takes the path of totality from Lake Superior to the other map, and 42-NE Moosonee continues the path from the Hearst-Cochrane map to James Bay. These areas are fairly well north and rather sparsely settled. As a result they have not been as accurately mapped as the more populous southern parts of Ontario.

To get a little more specific about where to go in Ontario, we looked into the vacation literature. Ontario has been divided into 52 vacation areas, with literature available about things to do, living accommodations, transportation, and so on, for each area. The eclipse path across Ontario goes through areas 42, Superior-Longlac region; 38, Oba-Hornepayne country; 39, Hearst-Kapuskasing area; and 40, Moosonee and the Goose country. The Department of Travel and Publicity, Parliament Buildings, Toronto 2, distributes this vacation literature free.

These leaflets are good to have for a trip into Canada, for in them are the Canadian rules and regulations that should be observed, as well as things to do and see which are particularly of interest if eclipse observing is part of a vacation. There is also available a sheet for each area, titled "Where to Stay," listing motels, hotels, and camps, with their prices and facilities.

Another important factor in eclipse observing, of course, is the weather. In response to a letter, a 10-year average at four observation stations at 7:30 EST in northern Ontario was supplied by the Air Services Meteorological Division of the Department of Transport, 315 Bloor St. W., Toronto 5. In general this average indicated a probability of about one in five of having a clear sky in the early morn-

(Continued on page 56)

Sky and TELESCOPE

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COVER: The aurora borealis, seen toward the southwest from Goose Bay, Labrador, at about 9 p.m. EST, on March 20, 1953. Sirius and Orion shine through the rapidly brightening lavender and green bands and draperies. M./Sgt. James H. Godsey, Jr., who took this aurora picture and many others in this issue, writes that amateur photographers have opportunity to record the northern lights at Goose Bay at least once a month and sometimes for two or three nights in a row during the winter months. (See pages 35 and 40.)

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The northern lights over Goose Bay, Labrador, on the evening of January 27, 1953, photographed by M./Sgt. James H. Godsey, Jr., of the U. S. Air Force. He used a 4 x 5 Speed Graphic, f/4.7, with exposure times from 45 to 60 seconds for this and the pictures on page 37.

Solar Eclipses and the Aurora Borealis

By Sydney Chapman* and D. W. N. Stibbs**

IN LONDON in 1952, at a meeting of the joint permanent eclipse committee of the Royal Society and the Royal Astronomical Society, data for future total solar eclipses were circulated, and among them a Nautical Almanac Office map of the areas affected by the eclipse of June 30, 1954. The first author of this article noticed that the track of totality crossed the northern auroral zone, and remarked that a lookout should be kept for any aurora that might be visible during the eclipse. Some of the committee members expressed doubt as to the possibility of so seeing an aurora, owing to the brightness of the sky even during a total eclipse, whether or not a filter were used to cut down the sky background light.

This led to an examination of several points relevant to such observations: evidence for the occurrence of aurorae over the earth's sunlit hemisphere, that is, of daytime displays; possible differences between daytime and nighttime aurorae; the frequency of total solar eclipses in regions where the aurora is most likely to appear; the chance of an aurora during the 1954 eclipse; sky brightness during a total eclipse compared with the brightness of night aurorae; and the possibility, nature, and value of observations of an aurora during next year's eclipse. These six points will be taken up in turn.

1. *The occurrence of daytime aurorae—indirect, visual, and radio evidence.* Strong auroral activity is always associated with notable magnetic disturbance in high latitudes; the magnetic data indicate the existence, at such times, of concentrated electric currents (or electrojets) in the polar ionosphere. These flow along the auroral zone, that is, the zone of maximum auroral frequency delineated successively by Loomis, Fritz, and Vestine from long series of auroral data, and (except by Vestine) entirely without reference to magnetic storm phenomena and data. During magnetically disturbed periods, the magnetic data indicate the presence of the electrojet along the sunlit or daytime part of the auroral zone, where aurorae themselves cannot be seen even if present, because of the sky brightness. However, it has long seemed likely to investigators of geomagnetic disturbance that aurorae will be associated with the exceptional ionization along the course of the electrojets, by day as well as by night.

There have been many mistaken reports of aurorae being observed by day, when what was seen was only delicate cirrus cloud. On the other hand, after a notable aurora has passed its maximum intensity and while it is still night, the sky may *appear* to be covered more or less uniformly by cirrus clouds, illuminated as if by moonlight. Actually, the light proceeding from the apparent cirrus is totally different from moon-reflected sunlight; it is unpolarized emitted light, largely that of the atomic oxygen auroral line at 5577 angstroms.

One of the most outstanding daytime aurorae credibly reported is that of Sunday, May 15, 1921, during a very great magnetic storm (see *Geomagnetism*, Chapman and Bartels, Oxford University Press, pages 328, 331, and 475). This storm reached its maximum intensity during the first few hours, Universal time, of that day, when the horizontal magnetic intensity in low latitudes fell by nearly three per cent (namely, by 1,000 gamma); the aurora was seen at the time at Apia, Samoa, in

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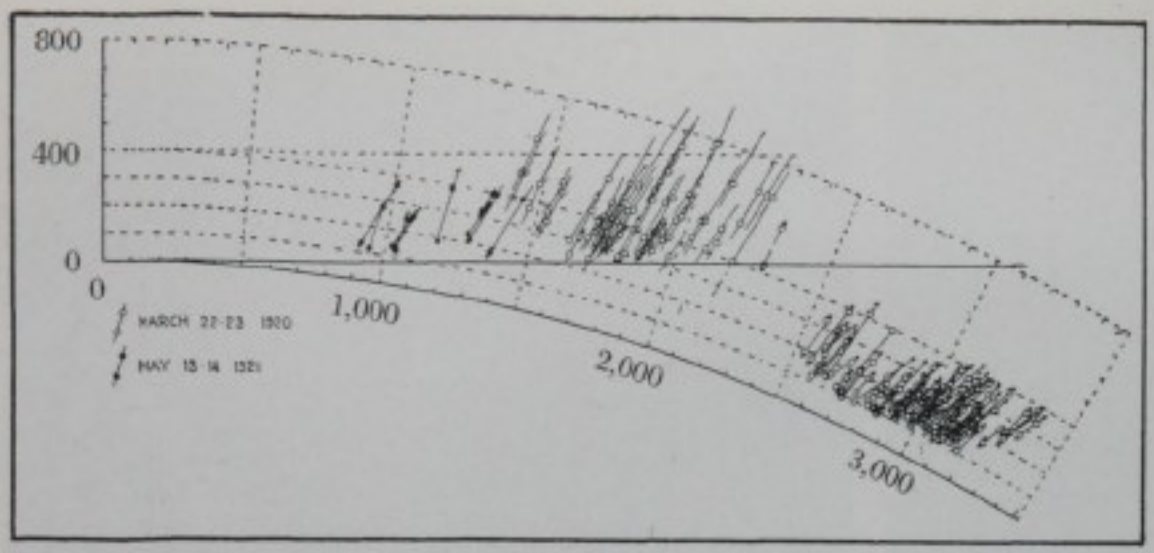


Fig. 1. Positions of sunlit rays and draperies (to the left) and of aurorae in the dark atmosphere (to the right) are shown here relative to the earth's shadow, which is bounded by the horizontal line tangent to the earth's surface. Horizontal and vertical distances are in kilometers. After Störmer.

latitude 13°.8 S., longitude 171°.8 W., at an altitude of 22 degrees. The reports of its appearance in broad daylight, however, came from two reliable observers in the northern island of New Zealand. The following information has been kindly supplied by the Carter Observatory at Wellington, from both published and unpublished data.

J. Fraser Paterson saw it from Taumarunui (38°.9 S., 175°.2 E.) before 3:30 Universal time the same day, over two and three quarter hours before local sunset at 5:45 p.m. New Zealand time. The season in New Zealand was then, of course, five weeks short of midwinter. The "cloudless sky was illumined with a pronounced pink tinge, from about 40° east to 40° west of south. The height of this aurora was about 50°. The pink shade changed to red with the approach of sunset." Later that day, after sunset, the continuing brilliant auroral display was watched by him and many others.

On the same afternoon but rather later (4 p.m. NZT), C. G. G. Berry saw the aurora in daylight from Wellington (41°.2 S., 174°.7 E.), about 160 miles farther south; the sun's altitude at the time was about 12 degrees, in the direction 51 degrees west of north. The sky color was a "deep crimson," which "seemed to be superimposed on a sort of bluish haze." He said it was probably the color that first attracted his attention. The color extended from the south to the southeast, approximately; his position was such that its westerly extension could not be seen. No definite form was observable, nor any motion—it was simply a great expanse of glow. Being an experienced observer, he was certain at the time that it was an aurora; it could not be confused with a sunset glow, the earth's shadow, or other effects. In this case, also, friends confirmed the observation, but have left no written record of it.

A daytime aurora was seen by O. Mohler on the evening of September 18, 1941; on the 17th there had been a bright display, and only 15 minutes after the sun had set on September 18th the sky in the northwest, seen from the McMath-Hulbert Observatory, in Michigan, was a very bright green. This aurora was seen earlier by Helen Dodson, less than 25 minutes after sunset, at Wellesley College, in Massachusetts.

Störmer recorded an unusual (though much less outstanding) aurora seen during dawn, when the sun was less than six degrees below the horizon and only a few of the brightest stars were visible.

Apart from the rare visual evidence, the most reliable—and much more frequent—indication that aurorae occur over the sunlit hemisphere of the earth is afforded by radio echoes reflected or scattered by aurorae. At night, short-wave signals are returned occasionally from regions some hundreds of kilometers to the north or northwest, and the association of this phenomenon with aurorae has been carefully examined and confirmed. Similar echoes sometimes received in the daytime are with confidence interpreted as indicating aurorae over the sunlit hemisphere; and at Jodrell Bank some preliminary indications have been found of a variation in the frequency of such aurorae during the daylight.

2. *Possible special characteristics of daytime aurorae.* Even if there were no

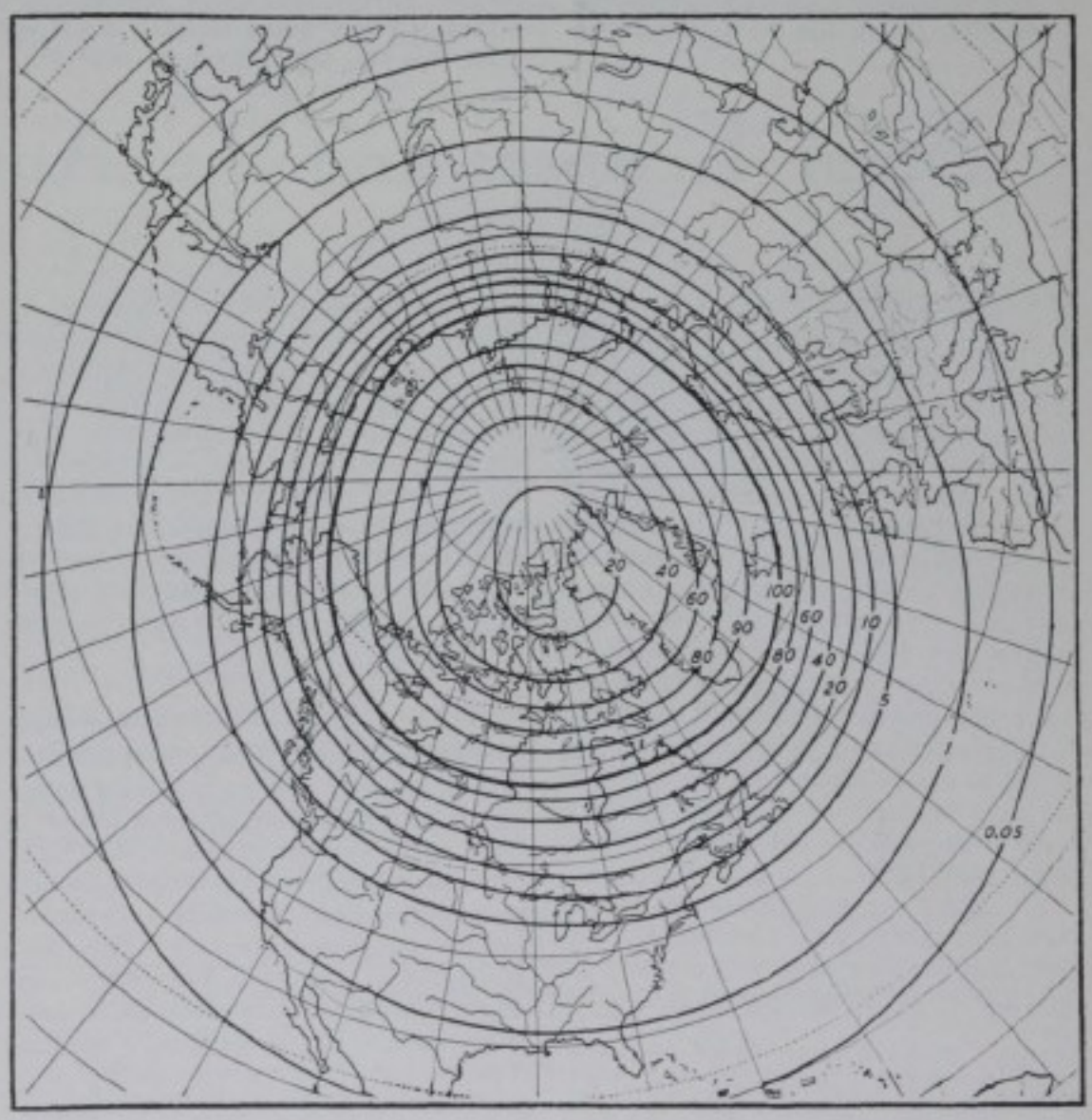


Fig. 2. The frequency of occurrence of aurorae in the Northern Hemisphere is shown here, according to Vestine. The numbers attached to the contour lines indicate the percentage of clear nights on which aurorae can be observed. In high latitudes, it is assumed that two thirds of the days of the year are suited to visual observation of the aurora, and the 100-per-cent line corresponds to 243 displays annually. Adapted from "Terrestrial Magnetism and Atmospheric Electricity."

prior reasons for supposing daytime aurorae would differ from those seen at night, it would be desirable to take any opportunity of observing daytime occurrences, to establish the lack of difference or to find the difference if there be any.

Night aurorae appear to be produced by the entry into our atmosphere of fast-moving charged particles, protons in particular, coming from the sun, and guided toward the polar regions by the earth's magnetic field. It is reasonable to suppose that these particles, which enter all along the night portion of the auroral zone, enter also along the sunlit portion; but it is not possible in the present rudimentary state of the theory of aurorae to infer with any confidence that there should be a difference in the density and speed of the particles impinging in the two parts of the zone.

However, there is certainly a difference, between day and night, in the state of the atmosphere which they enter; though again we are still ignorant of many aspects of the difference.

Perhaps the most definite indication that a notable distinction may exist between day and night aurorae is given by Störmer's studies of sunlit compared to night aurorae (Fig. 1). He observed several aurorae which, though seen at night from places on the ground where the sun had set, were actually located in the sunlit atmosphere lying outside the earth's shadow. These were seen to the west after sunset or to the east before sunrise. They differed strikingly in height from ordinary aurorae seen inside the earth's shadow. The aurorae in the sunlit atmosphere had mean and maximum altitudes around 300 and 1,000 kilometers, respectively, instead of about 100 and 500 kilometers as for most night auroral displays. This is shown by the average over all auroral forms, and also by auroral rays.

Harang has studied auroral forms with great horizontal extension, such as bands and arcs, which could be seen partly in the shadowed and partly in the sunlit atmosphere. In the sunlit air the heights showed a steady increase from 100 kilometers in the border region up to 120 to 130 kilometers in the sunlit region.

Störmer also found differences in color and spectrum between night and sunlit aurorae; many of the latter were grayish rather than yellow-green (the most common color of night aurorae). Some spectra showed a strong decrease of the green line 5577 compared with the violet nitrogen bands. On some of his photographic plates auroral rays appeared that were not seen visually; their light must have been confined to the ultraviolet. Other spectra of sunlit aurorae, taken by Störmer and Vegard in Oslo, showed a very strong enhancement of the red oxygen doublet 6300-6364 compared with 5577, and Störmer on a few occasions photographed red sunlit rays, and also blue sunlit rays. In the latter the spectrum showed very strongly both the red oxygen lines and the blue nitrogen bands.

These differences are all found from aurorae that lie in regions where the sun's zenith distance is nearly 90 degrees. It may well be that where the sun's rays are less inclined, the daytime aurorae differ still more from night aurorae.

Finally, the observations of daytime aurorae made in New Zealand in 1921 indicate that the luminosity can very greatly exceed that of the brightest night aurora; and although this was a quite exceptional occasion, it suggests that also during more ordinary periods the day aurorae may be brighter than those at night.

3. *The frequency of total solar eclipses in auroral regions.* Total solar eclipses can occur in all latitudes, from the equator to the poles. Aurorae are more selective; they occur most frequently along the auroral zones, northern and southern. By the auroral zone will here be meant the region between the lines given by Vestine for 90-per-cent frequency of visibility on all possible nights (Fig. 2), nights with a clear dark sky. In the Northern Hemisphere, these lines lie respectively about one degree south and 3½ degrees north of the line of 100-per-cent visibility; they are based upon data extending over many years. Owing to the sunspot cycle, the number of aurorae seen *at places well outside the zone* varies considerably; but in the auroral zone there is the same 90- to 100-per-cent frequency of visibility even in sunspot minimum years (such as the Second International Polar Year of 1932-33), though the aurorae then seen there are more often weak or moderate than strong.

An aurora lying over this zone may be well visible (when the sky is dark, either by night or during an eclipse) at an elevation of 30 degrees at a distance of about 170 kilometers from the point vertically below the aurora, if the latter is at a height of 100 kilometers. If daytime aurorae are higher (like many seen after nightfall, but lying in the sunlit air), their distance of visibility may be twice this or more. On this account the auroral zone might be widened a little to the north and south, in inferring the region in which there is a good chance of seeing a daytime aurora on a day of eclipse.

Only those eclipses whose tracks of

This sequence of three aurora pictures, March 20, 1953, was made within four or five minutes at about 7 p.m. EST, with Sgt. Godsey moving forward between the 35-second exposures. The wide feature of the top picture split into two rayed bands, and in the third picture the left-hand formation had faded out while the right-hand one increased in intensity.

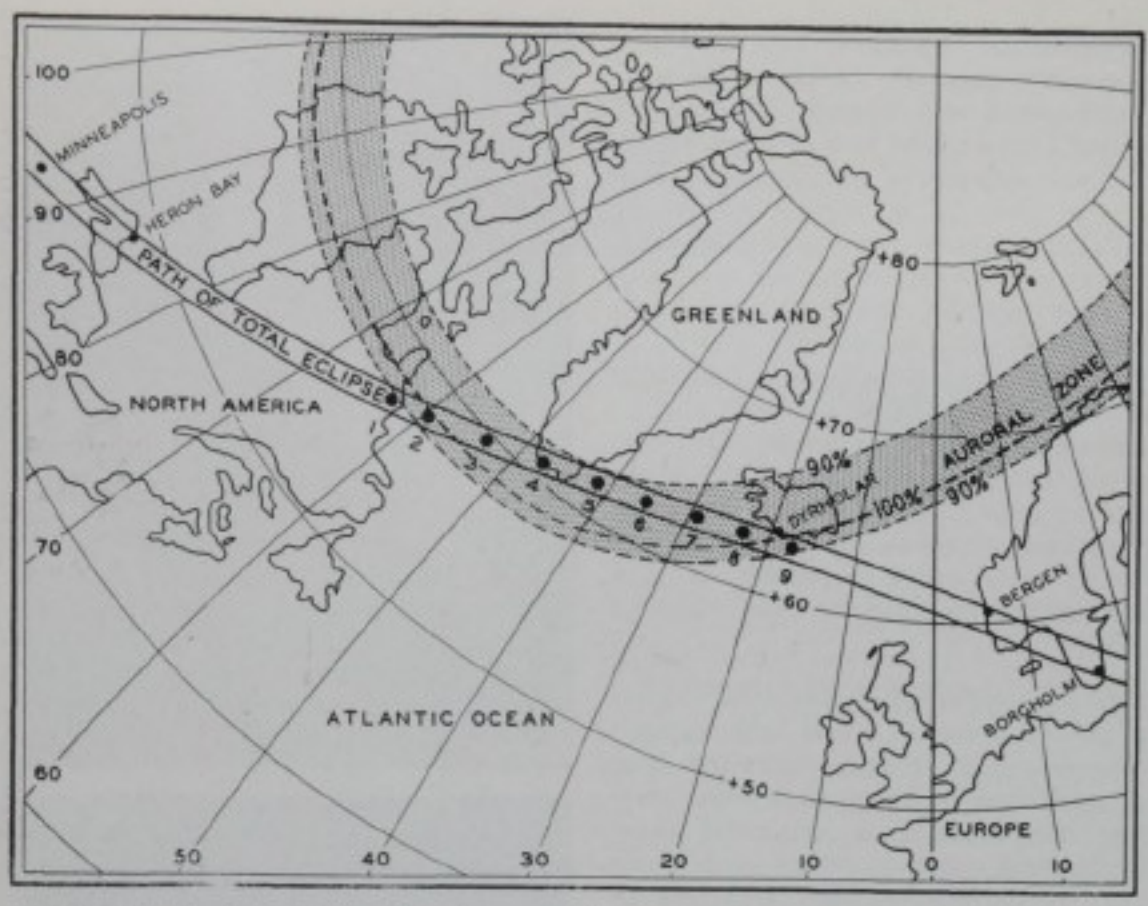


Fig. 3. Next year's total eclipse track crosses the auroral zone for about 1,400 miles. The numbers correspond to those in the table on page 39. Diagram by D. C. Wilder, Geophysical Institute, University of Alaska.

totality lie partly over the auroral zone seem likely to afford a good chance (sky brightness permitting). The rare exceptions will here be ignored, when an eclipse coincides with a great magnetic storm, during which the aurora may extend much beyond its usual limits of latitude. In the case of an eclipse whose track of totality lies outside the auroral zone, the chance of an aurora being visible from the track on the eclipse day might with some probability be inferred a few days earlier or, at most, three or four weeks before the day.

Oppolzer's *Canon der Finsternisse* contains maps showing the central lines of annular and total eclipses of the sun, for more than 3,300 years from 1207 B.C. to A.D. 2161. During this period it is likely that the auroral zone has remained nearly the same as now. In the 500 years from A.D. 1650 to 2150, the central lines of 49 *total* eclipses pass across the Northern Hemisphere auroral zone, or approximately one per decade; but their time distribution is not uniform, nor are they all equally well suited for the observation of daytime aurorae. (Annular eclipses need not be considered, owing to the much greater sky brightness even during their maximum phases.) The most favorable cases are those in which the sun's altitude is not too low where the track crosses the zone, and in which this crossing is not at too great an angle (which cuts down the time available for auroral observation). Next year's eclipse is particularly favorable in both these respects (Fig. 3), as its track lies for over a thousand miles within the zone, and during much of that length the sun's altitude is considerable — from 28° to 49°.

Of the 49 "auroral" eclipses above mentioned, 11 appear to be especially favorable for auroral observation; 32 are only moderately favorable; and six, poor. The time distribution of the 49 and the 11 special eclipses, half century by half century, is:

Period	1650	1700	1750	1800	1850	1900	1950	2000	2050	2100	2150
All "auroral" eclipses	3	5	6	3	3	5	9	6	5	4	
Favorable cases	2	2	0	1	1	1	4	0	0	0	

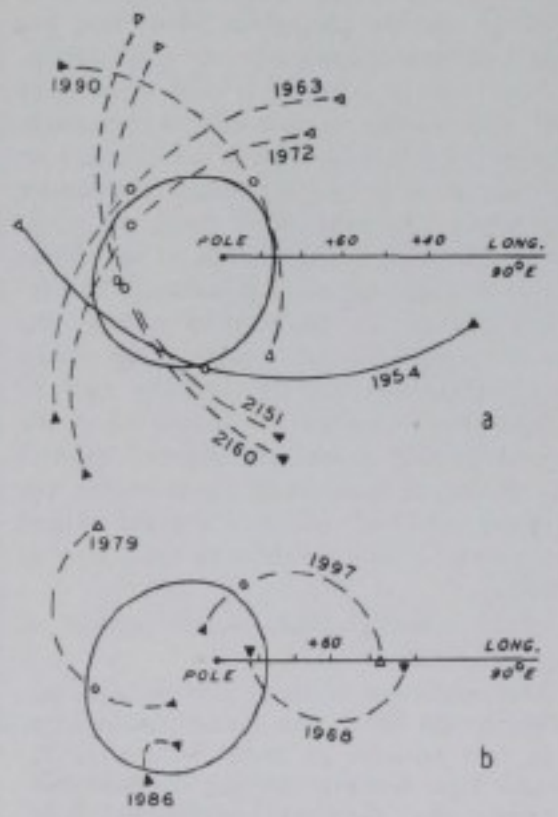


Fig. 4. These eclipse tracks, from Oppolzer, show those that cross the auroral zone (the 100-per-cent line is oval shaped), beginning with the eclipse of 1954, which is a solid line.

Thus it is clear that the present half century is specially favored by auroral eclipses, and particularly by having four of those most favorable.

The dates of the 11 most favorable cases, and of another two that will occur shortly after 2150, are:

Past eclipses	*Future eclipses*
1652 April 8	1954 June 30
1688 April 30	1963 July 20
1724 May 22	1972 July 10
1726 Sept. 25	1990 July 22
1833 July 17	2151 June 14
1860 July 18	2160 June 4
1927 June 29	

It appears that in the present century one favorable opportunity has been missed, that in 1927, near the sunspot maximum of 1928.4. However, the instrumental possibilities of observing a daytime aurora on that occasion, and the availability of good aircraft, must have been decidedly less than they will be next year. So far as we know, no question of auroral observations during the 1927 eclipse was raised at the time.

Though the present half century is especially favored with "good" auroral eclipses, the intervals between the 1954 eclipse and the next two "good" occasions are each half a saros (nine years), and the following good eclipse occurs a whole saros (18 years) later.

In Fig. 4a are shown, in relation to the 100-per-cent auroral line, the central lines of next year's eclipse (drawn in full) and of the five succeeding good auroral eclipses. In each case the progression of the shadow along the central line is counterclockwise; the local noon point is marked by a circle, and the end points by triangles (open for sunrise, solid for sunset; for some eclipses the central line passes from one sunrise to another, or from one sunset to another, with no noon intervening). In Fig. 4b the central tracks of the other (less favorable) auroral eclipses during the present half century are drawn. These illustrations make it clear that next year's eclipse offers a rare geographical opportunity for seeing a daytime aurora, if such an observation is possible.

4. *The chances of an aurora occurring during the 1954 eclipse.* At places well outside the auroral zone, aurorae are most frequent during or near the maximum years of the sunspot cycle, but next year will be at or near sunspot minimum. However, as already indicated, aurorae are visible every or almost every clear, dark night from the auroral zone, though in sunspot minimum years they are most commonly weak to moderate in intensity. Hence, so far as we can judge, next year's eclipse is not unlikely to be favored with a weak or moderate daytime aurora.

Aurorae vary in frequency throughout

the year, being more numerous or stronger near the equinoxes than near the solstices. But all the good auroral eclipses for the next century occur near midsummer. The true frequency of aurorae, apart from visibility, is likely to be much the same at the two solstices, though in the north in June the short summer nights permit fewer to be seen than in winter. In Sweden in midwinter the auroral frequency is only one third less than at the equinoxes.

There is a pronounced maximum of auroral frequency near local midnight. It is not possible to judge from auroral theory whether there is another daytime maximum.

5. *Sky brightness during a total solar eclipse compared with the brightness of (night) aurorae.* We have examined the available evidence as to the sky brightness during a total solar eclipse; the details will be given elsewhere. The results, for different eclipses, obtained differently by different observers, show a considerable range. Here they will be expressed in erg units, signifying ergs per square centimeter per second per steradian. The visual range is 0.45 to 4.4 erg units, for a point in the sky at an altitude about eight degrees higher than that of the eclipsed sun. It is difficult to be sure how far this range represents a real variation between different eclipses, and how much is due to errors of observation and interpretation. In the following a middle value of two erg units will be adopted for discussion.

Data for the absolute over-all brightness of auroral surfaces are hard to find, but it seems that none but an exceptionally strong aurora could be seen with the unaided eye from ground level, against a sky background of two erg units brightness. Barbier and Pettit (*Annales de Géophysique, 8,* 232, 1952) have given measures of the absolute brightness of the auroral light of the green line 5577, isolated by a filter, and measured by a photoelectric photometer. Though their results are expressed differently, we infer the monochromatic brightness in erg units varies from 0.03 for a moderate aurora to 0.3 for a strong aurora, though still greater values may occur. The use of a filter centered on 5577, and of 60 angstroms band-width, as used by Barbier and Pettit, would reduce the sky background to 0.1 erg unit; but if a band-width of no more than six angstroms is available, this is reduced to 0.01, which would permit a moderate aurora (by nighttime standards) to be seen through the filter, if the filter absorption were not too great.

The use also of a polaroid would reduce the auroral light, which is unpolarized, by one half, and the sky light, partly polarized, by more than one half (choosing the most favorable orientation of the polaroid). This might be helpful if the additional absorption involved were permissible.*

A further advantage to the auroral as compared with the background light would be gained by observing from an aircraft: The sky brightness would be reduced, whereas the auroral brightness would if anything be greater owing to less atmospheric absorption.

6. *Suggested observations during the 1954 eclipse.* Though radar beams can detect the presence of a daytime aurora, they cannot *see* it (at least not yet), and they do not tell us whether daytime aurorae have the same form, color, and intensity as nighttime aurorae.

Possibly future daytime aurorae may be photographed from rockets, which have so much extended our knowledge of the solar spectrum in the ultraviolet region. But aurorae are so faint that it will be harder to photograph them, and certainly very expensive.

Hence it seems worthwhile to use the opportunity afforded by the eclipse of June 30th to watch for daytime aurorae with the aid of suitable filters (and perhaps also polaroids), from aircraft flying along the path of totality within the auroral zone. The observations may be visual, but if possible they should also include photographs, so that an objective record may be gained. The filters used should include some to isolate the green line 5577; they might also usefully include some to isolate the stronger (6300) of the two atomic oxygen red lines 6300 and 6364, and some to isolate a nitrogen band in the ultraviolet.

If intensity measurements can be made, this too would be very desirable; and new measurements of the brightness of the sky during eclipse might be made, perhaps best from ground level. If a quiet auroral arc should be visible during the eclipse, it might be possible to determine its height, by observation from two latitudes within the band of totality, though this would be far from easy, especially if the arc were much above 100 kilometers.

Though the total eclipse is brief at any one spot on the ground, observers in aircraft following the shadow along the track should be able to lengthen their time of totality; this increases both the probability of auroral occurrence during the interval and the time available for observations of different kinds.

The table, kindly supplied to us by D. H. Sadler, superintendent of the British Nautical Almanac Office, gives eclipse data relevant to such observations, for the whole time of passage of the shadow along the auroral zone.

If present, the aurora would seem likely to be seen near the zenith, well above the altitude of the eclipsed sun and its corona. Observers may, of course, fail because of the absence of aurora, but in such a disappointment they would be one with many past eclipse expeditions whose plans have failed because of the presence of cloud. And if there be no aurora, observers above the clouds will have the grand spectacle of the eclipse, and may be able to make useful measurements of the brightness and color of the eclipsed sky.

CENTRAL LINE OF TOTAL SOLAR ECLIPSE OF JUNE 30, 1954

Number on Fig. 3	*Universal time*	*Local mean time*	*Latitude north* ° ′	*Longitude west* ° ′	*Altitude of sun* °	*Azimuth of sun* °*E. of N.*	*Duration of totality* m s
1	11:24.7	7:10	56 55	63 40	28	90	1 54
2	11:28.2	7:30	58 06	59 32	30	95	1 59
3	11:33.5	8:00	59 36	53 22	34	103	2 05
4	11:39.0	8:30	60 48	47 15	38	112	2 11
5	11:44.5	9:00	61 43	41 08	40	120	2 16
6	11:50.2	9:30	62 22	35 04	43	129	2 21
7	11:56.0	10:00	62 46	29 00	45	138	2 25
8	12:02.0	10:30	62 56	22 59	47	147	2 28
9	12:08.0	11:00	62 51	17 00	49	157	2 31

*Experts on the application of interference and other types of filters may wish to communicate suggestions that will prove of value to both amateurs and professionals who undertake the observations proposed in this article.—ED.

LYMAN ALPHA

The Lyman-alpha line in the solar spectrum at 1216 angstroms has now been photographed by physicists of the University of Colorado, with a grazing-incidence spectrograph sent aloft in an Aerobee rocket. The exposure time was 28 seconds, at a missile altitude of 81 kilometers. Dr. William A. Rense describes this observation in the *Physical Review.* The line, the only one observed in the sun's far ultraviolet, is five angstroms wide and shows a narrow emission center with broad emission wings. Previously the solar Lyman-alpha line had been detected in May, 1952, by means of photon counters sent aloft in an Aerobee (*Sky and Telescope,* February, 1953.)

FELS PLANETARIUM ANNIVERSARY

On November 6, 1953, the Fels Planetarium of the Franklin Institute in Philadelphia celebrated the 20th anniversary of its opening. Over 2,510,000 visitors have seen demonstrations with the Zeiss projector during the first two decades of operation. Guest of honor at the celebration was James Stokley, of General Electric Laboratories, who was first director of the planetarium.

The display of March 20, 1953, by about 9 p.m. EST showed the development pictured here and on the front cover. The series on page 37 shows its appearance about two hours earlier. Between the time that Sgt. Godsey took the cover picture and those above he "had to dash back into the house to get warm and to load film." The sequence is from upper left to upper right, then to lower left and lower right, over an interval of some five to 10 minutes. The aurora had its "usual" greenish blue color. The camera was moved slightly to the left for the last exposure, in which most of Cassiopeia can be seen. Auroral photographs with this article are by M./Sgt. James H. Godsey, Jr., at Goose Bay, Labrador.

THE AURORA

By Donald S. Kimball, *Yale University Observatory*

"GREAT STREAMS of red and blue shot up along the northeastern horizon. . . . These streams would faint and brighten in such a wonderful manner, that we imagined some painter in the skies drew his great brush from the horizon up to 40 or 50 degrees, dipped with vermillion, then with sky blue, and then with white and flesh color." So the San Joaquin *Republican* described the great aurora of 1859 seen at Stockton, California.[1]

Probably few phenomena of nature so fascinate scientific and nonscientific observers alike as the aurora. Nevertheless, people living in high latitudes have become so familiar with its colorful displays as to accept them as normal parts of their surroundings. During long arctic nights the aurora writhes and twists in a multiplicity of forms and colors providing an awe-inspiring spectacle illuminating the entire sky.

In the Northern Hemisphere, displays are usually called the aurora borealis or northern lights, because they are chiefly seen in the north, while in the Southern Hemisphere they are known as the aurora australis or southern lights.

Historical records over 2,000 years old describe aurorae as "horsemen running in the air, in cloth of gold, and armed with lances like a band of soldiers." Although aurorae were known to the Greeks and Romans, their knowledge in most cases probably came from travelers. Only on rare occasions do southern Europe and the Mediterranean countries witness an aurora. Great displays may be seen as far south as the West Indies, and the aurora of August 28, 1859, was reported overhead in Texas and Florida, while on February 4, 1872, a display was seen in Bombay, India.

In this chart by Geddes and White, the auroral zone in south polar regions is not completely outlined, because of a lack of observational data from interior Antarctica. The circles indicate limits of visibility for normal aurorae from various observing stations. For some of these the polygons show the relative frequencies of aurorae observed in different directions. From "Terrestrial Magnetism and Atmospheric Electricity."

A typical strong auroral display seen from the northern United States frequently commences after sunset as a faint dawnlike glow above the northern horizon. An arc of silver light gradually emerges out of the glow and becomes brighter and more distinct. As the arc steadily moves up the sky, rays shoot upward from bright places which appear along its lower border. The rayed arc becomes irregular in shape and folds upon itself, resembling a large curtain. Luminous bands rise from the northern horizon and sweep across the sky. Rays now reach the zenith, where they form a fanlike corona, and the aurora is at its greatest intensity. After several minutes, forms grow dimmer, the sky becomes covered with a luminous veil and a faint arc reappears in the north, gradually merging into the glow of the night sky.

One does not often see such a definite progression as has been described above and, in some cases, changes occur so rapidly that there is doubt about their exact sequence. An observer may be watching activity near the northern horizon and suddenly become aware that a corona has formed directly overhead.

There are, however, several standardized auroral forms that are recognizable. Several publications listed in the references[2, 3, 4] describe and illustrate the principal types.

Aurorae occur on the earth chiefly within two oval-shaped zones centering around the geomagnetic poles. If viewed from the moon, the aurora would appear like two luminous clouds near the north and south poles on the dark side of the earth. The north geomagnetic pole is near Etah, Greenland, and the south geomagnetic pole is on the antarctic continent. Very infrequently, auroral displays are seen in tropical and subtropical regions.

In 1881 Fritz[5] published his well-known map showing the geographical distribution of aurorae in the Northern Hemisphere, based on the analysis of a great number of older visual records. Actually, credit for the first map showing distribution in the Northern Hemisphere should probably go to Loomis,[6] who published such a map in 1860. Over the antarctic regions, records are too few for a complete delineation of lines of equal auroral frequencies for the Southern Hemisphere. Reports from a number of antarctic expeditions were used by White and Geddes.[7] Later, Vestine and Snyder[8] were able to draw the zone of maximum auroral frequency over the greater part of the antarctic region.

Auroral theories are numerous, and in their historical sequence they have progressed hand in hand with our knowledge of physical science. The great display of February 4, 1872, was studied by the Italian astronomer Donati, who suggested that the source of its energy might be found in the sun. Loomis,[9] in 1870, wrote:

"We must . . . conclude that the black spot [sunspot] is a result of a disturbance on the sun's surface which is accompanied by an emanation of some influence from the sun which is almost instantly felt upon the earth in an unusual disturbance of the earth's magnetism, and a flow of electricity developing the aurora light in the upper regions of the earth's atmosphere. The appearances favor the idea that this emanation consists of a direct flow of electricity from the sun."

Loomis also drew a series of curves for the years 1776 to 1870 which compared

These draperies in the sky remained motionless for 80 seconds, on an evening in October, 1952, and Sgt. Godsey left the camera shutter open for that time.

the number of aurorae, the range of the magnetic disturbance, and the relative extent of sunspots.

Today, scientists have evidence that the aurora is caused by showers of electrified particles consisting of electrons and charged hydrogen atoms emitted from centers of disturbance on the sun's surface. Traveling at speeds in excess of 1,000 miles a second, these solar bullets shoot out into space, catch the earth in their path, and drench its atmosphere. This bombardment sometimes continues for several days.

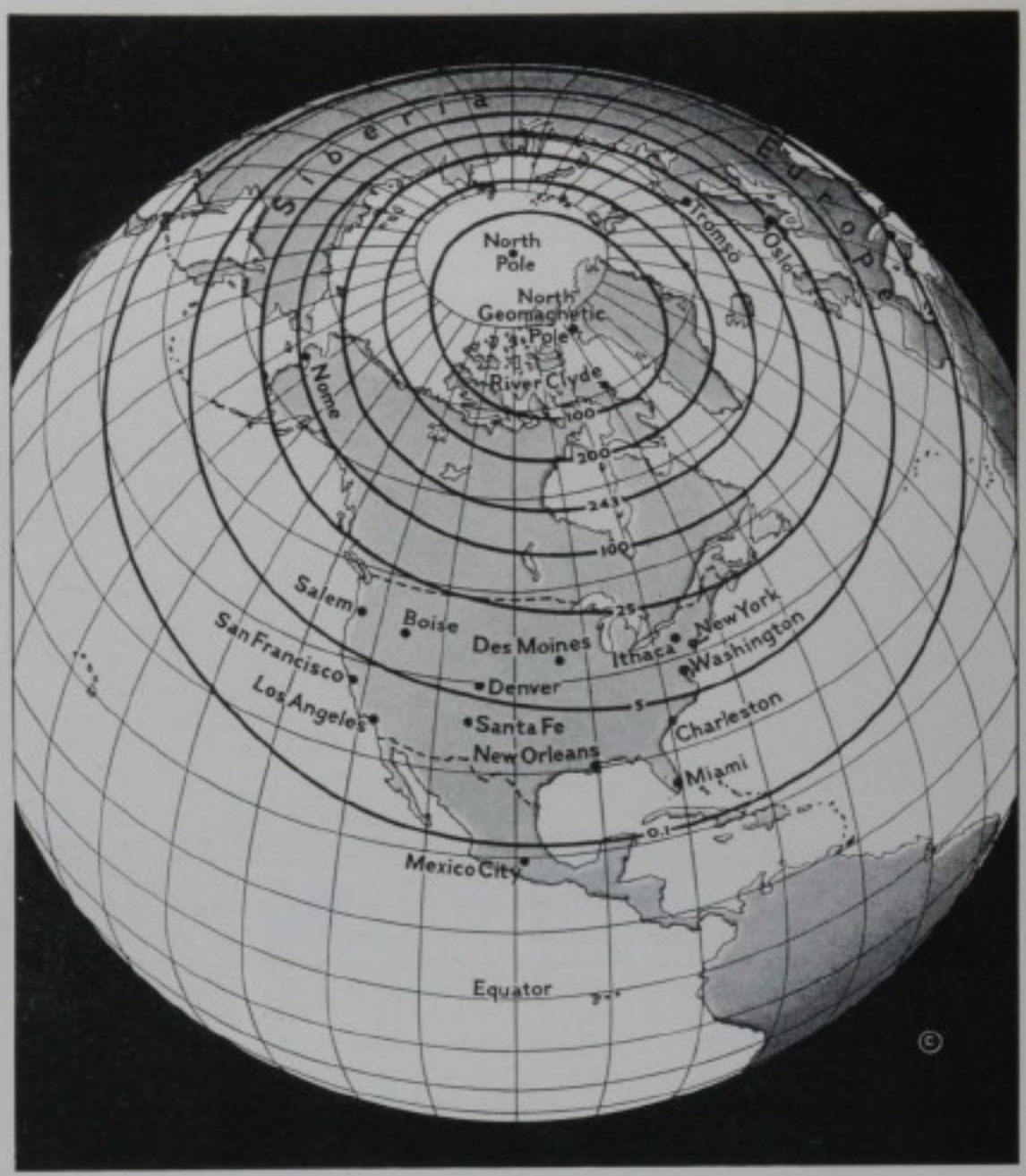
When one of these showers approaches the earth, the electrified particles are diverted by the earth's magnetic field down toward the north and south magnetic poles into the upper atmosphere, where the particles collide with atoms of rarefied air. The collisions excite the atoms so that they give off light resulting in the display that, as seen from the earth many miles below, is known as the aurora.

The same shower of solar particles that produces the aurora also interferes with the earth's magnetic field, causing magnetic storms. As early as 1741, Celsius and Hiorter in Sweden noted that a compass needle changed its direction by several degrees during bright aurorae. For hours at a time, during a magnetic storm, radio, telephone, and telegraph communication are made unreliable or even impossible.

Because they appear to be produced by the same forces, aurorae serve as tip-offs on magnetic storms. Since both tend to follow the sunspot cycle, it has become possible to forecast the long-range occurrence of magnetic storms and aurorae. However, sometimes brilliant auroral displays have been seen when few or even no sunspots were visible. The relation between sunspots, aurorae, and magnetic storms is complex and not readily explained.

The exact nature of the regions on the sun from which the charged particles emanate is still a subject for investigation. In addition to sunspots being associated with these sources, solar flares are often correlated with magnetic storms and spectacular aurorae. Generally, the time of passage for the corpuscular radiation from the sun to the earth appears to be about 24 to 36 hours. Meteorites, cosmic rays, and this corpuscular radiation from the sun appear to constitute the only extraterrestrial matter with which man has a close contact.

Aurorae play an important part in the exploration of the earth's upper atmosphere. Man lives on the floor of an ocean of air that is hundreds of miles deep and very complex in nature. At the present time, the upper atmosphere is under extensive investigation, by studying noctilucent clouds, the solar spectrum, meteors, radio propagation, sound-wave phenomena, the duration of twilight, the light of the night sky, and the aurora. Rockets have gathered direct evidence from heights as great at 250 miles, but the aurora enables us to probe the atmosphere to greater altitudes.



This map shows the estimated number of days per year of visible aurorae for the Northern Hemisphere, after Vestine, based on Fritz' data from 1700 to 1872 and on later data to 1942. Note that maximum frequency is centered on the geomagnetic pole, but there only about 50 displays per year are seen. Drawn by Harry S. Oliver.

Analyzing the light emitted by the aurora gives information on the kinds of gases present in the upper atmosphere, their physical condition, and their behavior when bombarded by incoming showers of electrified particles. The most easily observed auroral light comes from oxygen and nitrogen, the chief constituents of the atmosphere, but evidence is growing that showers of hydrogen nuclei (protons) may be the primary cause of the aurora. Recently, hydrogen has been rediscovered in the auroral spectrum,[10,11] but as early as 1885 Carlheim-Gyllenskiold[12] identified hydrogen in the visual auroral spectrum during observations in Spitzbergen. Current beliefs concerning the effects of these "hydrogen showers" were described by Otto Struve in this magazine two years ago.[13]

Although modern scientific equipment furnishes much important data on the aurora, visual observations are still necessary. Already, visual work has yielded significant information on the frequency of displays, their geographical distribution, their variation with the sunspot cycle, and the general sequence of forms during a display. By continued visual observations much can be learned about the structure of the aurora and the growth of an auroral zone during a display.

During the 19th century, some remarkable aurorae were observed. A number of reports, found in the scientific publications and newspapers of the day, may be of great value to modern students of the aurora, particularly the writings of such early investigators as Loomis, Olmsted,[14] and Carlheim-Gyllenskiold. Our list of references includes some of these important original sources.

To study the broader aspects of a display of northern lights, it appears necessary to rely on visual observations. For even a moderate aurora, 10 observatories equipped with all-sky cameras could not give adequate coverage for North

(Continued on page 44)

WHITE DWARFS--I

BY OTTO STRUVE, *Leuschner Observatory*
University of California

IN 1924 A. S. Eddington derived the theoretical relation between mass and luminosity for stars that obey the perfect gas laws, as sketched in last month's article. When he compared the theoretical relation with observational data, he found agreement not only for such diffuse stars as Capella, whose mean density is about that of air, but also for red dwarfs like the sun whose material is denser than water, and the double star Krueger 60 which is as dense as iron.

Eddington was much surprised that so wide a variety of stars obeyed the mass-luminosity relationship. In his own words, "Something very different was being sought for," namely, the departure of dense stars from the theoretical mass-luminosity relation that might result from a failure to conform to the equation of perfect gases. (The pressure is proportional to the density and the temperature of the gas and inversely proportional to the mean weight of the particles.)

But "the big terrestrial atoms which begin to jam at a density near that of the liquid state do not exist in the stars. The stellar atoms have been trimmed down by the breaking off of all their outer electrons. . . . Consequently we can go on squeezing ever so much more before these tiny atoms or ions jam in contact. At the density of water or even of platinum there is still any amount of room between the trimmed atoms; and waste space remains to be squeezed out as in a perfect gas." [1] In other words, the perfect gas law remains in force for all the stars of the main sequence. As W. H. McCrea says[2]: "All other [than the white dwarfs] known stars . . . conform more or less closely to the mass-luminosity relation. Indeed, the foregoing discussion [similar to that outlined in our previous article] makes it appear rather difficult for a star not to conform!"

Yet a truly enormous number of stars in our galaxy are of the "nonconformist" type, predominantly the white dwarfs, of which the most famous representative is the faint companion of Sirius. The following simple computations will demonstrate the peculiar properties, large relative mass, small luminosity, extremely high density, that are characteristic of this and other white dwarfs.

In 1844 F. W. Bessel found that the proper motion of Sirius is not uniform, but roughly sinusoidal, with a periodicity of 50 years in the length of the waves. Eighteen years later Alvan G. Clark first saw the faint star, Sirius B, whose attraction upon Sirius A produces the irregularity of motion detected by Bessel. The parallax of Sirius is 0.38 second of arc, and the angular size of the orbit of B around A is 7.6 seconds; therefore the linear size is 7".6/0".38, or 20 astronomical units (about the distance between Uranus and the sun).

Kepler's third law tells us that the total mass of a double star, in terms of the mass of the sun, is equal to the ratio of the cube of the orbital semi-major axis to the square of the period, $20^3/50^2$, or 3.2. This total mass must be shared between Sirius A, which from its normal spectrum has a mass of about 2.2 suns, and Sirius B, for which there remains the difference, 3.2 − 2.2 = 1.

The existence of a massive companion to Sirius was first predicted by Friedrich Wilhelm Bessel, pioneer in precise astronomical measurements.

But Sirius B is about 10 magnitudes fainter than Sirius A, making its absolute visual magnitude about +11.3. (The sun has an absolute magnitude of +4.85.) Thus Sirius B emits only about 1/10,000 the light of Sirius A, and 1/400 the light of the sun. Yet, its mass is the same as the sun's, and if it obeyed the mass-luminosity relation it would emit the same amount of light as the sun, two ergs per second per gram. In reality it emits only 1/200 erg per second per gram.

Also, from the work of W. S. Adams we know that Sirius B has approximately the same color as Sirius A. Their surface temperatures are thus the same. The only way we can explain the 10,000-times deficiency in the total light of Sirius B is to suppose that its surface area is 10,000 times smaller than that of Sirius A. This makes its radius the square root of 10,000 or 100 times smaller than Sirius A, which is itself about twice the sun's radius. Thus, Sirius B has a radius about 1/50 that of the sun, and only 1/125,000 the sun's volume. The masses are the same; therefore the density of Sirius B is 125,000 times the mean density of the sun.

Even more fantastic is the mean density of the star AC +70°8247. G. P. Kuiper has estimated that this white dwarf has a diameter only about 0.005 that of the sun, or about one half of the earth's. It is believed to be of about one solar mass, and its mean density must be 10 million times the solar density. W. Krogdahl[3] has computed (with

[1] **Stars and Atoms**, Yale University Press, New Haven, 1927, page 39.

[2] **Physics of the Sun and Stars**, Hutchinson's University Library, London, 1950, page 150.

The first man to see the companion of Sirius was Alvan G. Clark, while testing the 18½-inch telescope now at the Dearborn Observatory. He is shown here with Carl Lundin (right) during the assembling of the Yerkes 40-inch objective, still the largest in the world.

[3] **The Astronomical Universe**, The Macmillan Company, New York, 1952, page 393.

slightly different data): "At the surface of the earth a little 0.1 inch cube of average stuff from this star would weigh almost 1,300 pounds. At the surface of the star, however, this same pinch of material would weigh 2,200,000 tons, for the surface gravity of this white dwarf is calculated to be 3,400,000 times the earth's. Here a 150-pound man, though his body were as strong as steel, would be crushed to tissue thinness by his own 250,000 tons of weight. The enormous compressive force of the star's tremendous surface gravity causes its atmosphere to increase in density about a billion times through a depth of just 15 feet; consequently the whole atmosphere of this white dwarf is probably only 10 to 15 feet thick!"

The steep density gradient implied by the small size and large mass of the star has an interesting consequence pointed out some years ago by E. Schatzman. Just as on the earth the dense metals have sunk into the deepest core while the lighter substances, like water and especially the gases, have risen to the surface, so in a white dwarf all available hydrogen floats on top of a dense inner mass, and gives rise to a thin atmosphere of hydrogen-rich gases. The atmosphere is under heavy pressure from the attraction of the star as a whole, so that very broad hydrogen lines are produced —about as observed under pressures of many atmospheres in the laboratory.

The broadening of the hydrogen lines in stellar atmospheres is caused by the electrical fields of ionized atoms and free electrons which happen, in their random flights, to come close to a radiating hydrogen atom. This is related to the Stark effect in the laboratory. The amount of the broadening depends upon the pressure of the atmosphere, which in turn depends upon the surface gravity of the star. In an ordinary main-sequence star, for example the sun, the surface gravity is about 30 times greater than at the surface of the earth, but because of the very low density of the sun's reversing layer, the pressure is only a small fraction of one atmosphere. We have seen that in the exceptional case of the star AC +70°8247, surface gravity is about three million times greater than the earth's, which would make it about 100,000 times greater than the surface gravity of the sun. The corresponding pressure in the reversing layer would then be many atmospheres and the hydrogen lines would be broadened to such an extent that they would flow together into a fairly uniform continuum of absorption. This might explain why there are white dwarfs with purely continuous spectra. According to Kuiper, AC +70°8247 has such a continuous spectrum.

In other white dwarfs, the hydrogen lines are visible but they are usually much broader than in main-sequence stars of spectral type *A*. A study by Kuiper of the line profiles of two such objects, 40 Eridani B and Wolf 1346, has given surface gravities about 10,000 times greater than the surface gravity of the sun. Assuming that these stars have masses of the order of the sun's and about 1/100 the sun's radius, the computed surface gravity would be 10,000 times the sun's—as was found from the line profiles.

It must, however, be admitted that we have no satisfactory theory of the spectra of the white dwarfs. A few of them show fairly narrow hydrogen lines together with lines of iron and other metals. Others have strong helium lines and weak hydrogen lines. This might have been expected if the white dwarfs had consumed nearly all of their original hydrogen through nuclear reactions. L. Mestel has suggested that the hydrogen now found in the atmosphere of a white dwarf such as Sirius B may represent not the small remaining fraction of its original supply of hydrogen but gas which this star has collected from interstellar space during its long lifetime. It is therefore possible that some stars have collected a reasonably large amount of surface hydrogen while others have failed to do so, either because they never happened to travel through a region of space containing dense interstellar gas clouds or because their motions through such clouds may have been too fast for the process of accretion to operate.

About 25 years ago W. J. Luyten started a systematic search, on Harvard Observatory photographs, of faint stars having large proper motions. Nearly 100 million stars were examined with a blink instrument which compares two plates, taken some 25 years apart. About 100,000 stars were found to have measurable proper motions, of which some 3,000 had *large* proper motions. All these stars must be close to the sun, otherwise they would not show a measurable displacement in 25 years. Most of them appear faint, roughly of magnitudes 12 to 15. Located at distances of 10 parsecs or less, they must be very faint intrinsically —they are all dwarf stars.

From their colors, Luyten, in collaboration with E. F. Carpenter at the University of Arizona, divided the fast-moving dwarfs into two distinct classes. About 2,900 are ordinary red dwarfs of spectral type *M*; about 100 are white dwarfs of spectral types *B*, *A*, *F*, and "continuous." The last-named have no spectral absorption lines, not even those of hydrogen.

We can roughly compute on the basis of Luyten's work that within any large volume of space three per cent of all stars are white dwarfs. Ninety-five per cent are main-sequence stars. Two per cent remain for the other sequences, mostly the subdwarfs and subgiants. The giants and supergiants are exceedingly rare.

We have already seen that the white dwarfs depart from the mass-luminosity relation. According to Luyten they form a broad band in the Hertzsprung-Russell diagram, whose central line, though not quite parallel to the main sequence, departs from it about 10 magnitudes. The width of the band is about four magnitudes, and is thus much greater than the width of the main sequence.

Next month we shall attempt to reconcile the peculiar properties of white dwarfs with present theories of their origin and evolution.

(To be continued)

THE AURORA

(Continued from page 42)

America. The geographical extent and description of the aurora at its southern limit (in the Northern Hemisphere) can be obtained only by visual means, since most auroral observatories are located in or near the auroral zone. A program of visual work along these lines is being planned for the Third Geophysical Year in 1957-58.

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THREE WEEKS OF SYMPOSIA--II

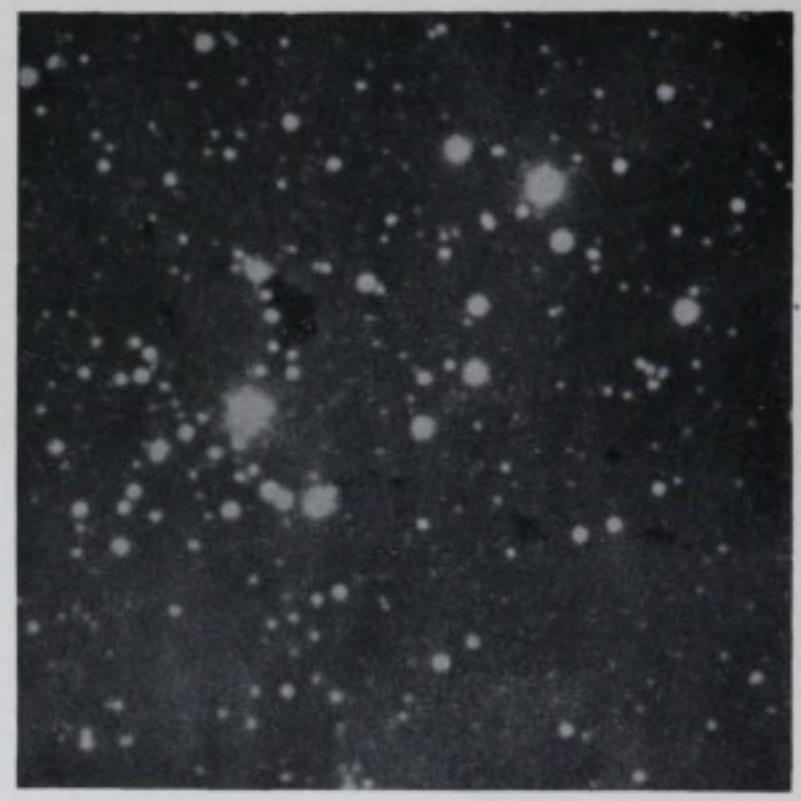
By BART J. BOK, *Harvard College Observatory*

THE CAMBRIDGE SYMPOSIUM ON THE GAS DYNAMICS OF INTERSTELLAR CLOUDS

AT CAMBRIDGE there were about 35 astrophysicists and 25 physicists and aerodynamicists. The symposium had the dual purpose of bringing together observational and theoretical astrophysicists, and of having them present their engineering colleagues with problems that the latter might be able to solve where the former fail. Since the interstellar medium has been studied in recent years by widely scattered groups and individuals between whom there had been little direct contact, the discussions were provocative; and it was indeed a pleasure to participate in the synthesis of very different points of view. Many new approaches were presented, and out of it all evolved a clarified picture of the physics of the interstellar medium.

The observational progress reported was dominated by the presentation of the amazing Milky Way photographs made in recent years by the new Schmidts, notably the 48-inch instrument on Palomar Mountain. R. Minkowski showed photographs made in red light of the Milky Way in Sagittarius-Scorpius and in Cygnus which revealed detail and structure of a hitherto undreamed-of variety. Most striking were the striated arcs of emission nebulosity (mostly due to hydrogen clouds) with parallel orientations over large areas of the sky. The gradually varying primary direction of the striae is highly suggestive of alignment by interstellar galactic magnetic fields. The sharpest emission features have diameters estimated to be no more than 1,000 astronomical units.

To supplement the Palomar photographs, there were exhibits of southern Milky Way pictures made at Harvard's Boyden station with the Armagh-Dunsink-Harvard telescope and with the small Perkin-Zeiss camera, and a group of photographs of emission features in the Magellanic Clouds by A. D. Thackeray, at the Radcliffe Observatory in Pretoria. The Radcliffe plates show a hitherto unsuspected prevalence of S-shaped emission features. The Harvard material has been analyzed by Dorrit Hoffleit, who found, in addition to a wide variety of new southern emission features (notably in the Carina section), about 150 new globules. These are small, roundish dark nebulae one light-year or less in diameter, that may mark the beginnings of yet unborn stars. She also has discovered a dozen larger dark and roundish nebulae with estimated diameters as great as five or six light-years. The Perkin-Zeiss camera shows in some parts of the sky almost perfectly circular emission features, whereas in other sections the emission nebulosities are torn to shreds in a turbulent mass, suggestive of strong stirring forces of unknown nature. The exhibit of celestial photographs was completed with the very fine Milky Way atlas prepared in recent years by Shajn and Hase at the Crimean Observatory (although no Soviet astronomers were present at the Cambridge symposium).



Many small black globules are seen in silhouette against a faintly glowing background of interstellar hydrogen around the open cluster IC 2944 in Carina. The smaller single globules are about 0.2 light-year across. Enlarged from a one-hour red photograph by W. D. Victor, May 28-29, 1951, with the ADH telescope in South Africa.

The work of the Dutch astronomers with the 21-cm. hydrogen line, mentioned last month, made a deep impression at Cambridge. The strong concentration of neutral hydrogen in the spiral arms of our galaxy and its virtual absence between the arms indicates that the arms are primarily composed of gas and dust and that the stars play a secondary role. The spiral structure of a galaxy thus becomes very much the concern of those interested in the gas dynamics of interstellar matter.

C. F. von Weizsaecker, of Goettingen, stressed the importance of the barred spirals as an initial stage in spiral formation, pointing out the stability of a ring structure and the lack of stability of the spiral features as we know them in our own galaxy and in M31. S. Chandrasekhar and E. Fermi, University of Chicago, have studied the stabilizing influence upon spiral arms in our galaxy that should result from magnetic fields roughly parallel to the direction of the arms. The spread in the directions of maximum polarization observed in the light of distant stars is taken to indicate the value of the galactic magnetic field. A field of some millionths of a gauss can account for the observed polarization properties and provide a mechanism for the stabilization of the spiral features. In the discussion, von Weizsaecker made the point that the lateral stability provided by magnetic alignment does not prevent disintegration of a spiral arm through shearing effects.

The principal problems facing the symposium were summarized by van de Hulst. He considers the major achievement of recent years to be the discovery that stars are evidently being formed continuously from interstellar gas. This applies especially to the *O* and *B* stars found in rapidly expanding groups or associations. He asked why all of the interstellar matter was not collected in stars, in other words, how some of the gas might be returned by the stars to the interstellar medium.

Then he mentioned that, since the first symposium of this kind (at Paris in 1949), astrophysicists had gradually come to realize that cosmic dust contributes relatively little to the total mass of interstellar matter. Rather, it is useful only as a tracer for structural details in the abundant but mostly invisible gas, which drags the dust particles along with it. There was not complete unanimity on this point, and all agreed that the relation between gas and dust would require continuing investigation.

There was, however, general acceptance of van de Hulst's next point, that the dust, along with certain molecules, provides a cooling agent of major importance. For we find near the central plane of our galaxy apparently two very

different varieties of cosmic gas clouds. Most readily observed are the H-II regions of ionized hydrogen, with temperatures of the order of 10,000 to 15,000 degrees absolute. There are also the H-I regions, mostly of un-ionized hydrogen and possibly certain molecules, where the temperatures are 50 to 100 degrees absolute; these occur especially in and near the great dust clouds.

One of the principal new views that I brought back with me was that the difference in temperature between the H-I and H-II regions has important consequences for the equilibrium between them. An H-II region exists primarily around a very hot *O* or *B* star (where there is a plentiful supply of ionizing ultraviolet radiation) and it is generally surrounded by an H-I region. If the atomic densities in the two regions are identical, the higher temperature of the H-II region will produce a very much greater pressure there, and it should almost certainly be expanding into the H-I region. This idea was originally proposed by L. Spitzer, of Princeton, and it has since been elaborated by several participants in the Cambridge symposium, notably L. Biermann, of Goettingen, Oort, and H. Zanstra, of Amsterdam.

Oort took the point of view that the association of dense gaseous nebulae with *O* and *B* stars is not simply a chance one, but that they belong together. He gave reasons why the absorption features —dark narrow fringes and strings, as well as the globules—should result from the compression that would accompany the expansion of a hot region into a cooler one.

The cloud structure of the interstellar medium continues to present a challenge. The smallest observed gas condensations in planetary nebulae have diameters of not more than 200 astronomical units. The best-known dust concentrations are the tiny globules; the smallest observed to date have diameters of a few thousand astronomical units. The largest of the single and well-defined dust aggregations have diameters of the order of 200,000 to 300,000 astronomical units. There is still rather strong disagreement on whether or not the globules represent as marked concentrations of gas as of dust. From these small units, the observer progresses to the interstellar gas clouds (revealed by interstellar absorption lines in the spectra of stars) with diameters of the order of 50 light-years, and the large dust complexes with diameters of several hundred light-years. Why do these various types of clouds exist and what holds them together? With the exception of the globules, gravitation probably plays only a minor role in their formation and evolution; turbulence and magnetic fields are probably the major agents holding them together, with shearing by galactic rotation providing a strong disruptive force. Definite answers to these questions might throw some light on the problems of star formation.

Zanstra dealt with the formation of small, cool gaseous condensations in planetary nebulae. He demonstrated that under certain well-defined conditions of temperature, density, and composition of a gas, cool condensations would naturally form in a gaseous cloud. Zanstra's study adds another possible mechanism to the small list of processes that may lead to cloud formation in gas or dust, namely, gravitational collapse, the effects of radiation pressure on solid particles, and certain magnetic and hydrodynamical effects.

F. D. Kahn, of Manchester, has studied what happens when two interstellar gas clouds collide. He showed that on the basis of the currently accepted picture of gas clouds with diameters of the order of 25 light-years, spaced 300 light-years or so apart near the galactic plane and moving with speeds of the order of five kilometers per second, any one cloud should bump into some other cloud about once every two million years. The consequences of such a collision depend on whether they hit head on or suffer a partial collision. In the first case, a single merged cloud will almost certainly result. In the second case, the two clouds may be partly broken up, with the parts not in line of collision breaking away from the remainder and each going its own way, and with the colliding parts merging into a third unit.

There seems, however, no escape from the conclusion that the result of any collision will almost certainly be a heating of the colliding parts to temperatures calculated by Kahn to be close to 3,000 degrees absolute. How do these clouds, so heated by collision, radiate away their energies to return to their customary temperatures of 50 to 100 degrees? Kahn expects that "ice splinters," tiny particles with diameters of the order of a millionth of a centimeter, very much smaller therefore than the particles that produce interstellar reddening and absorption, are sufficiently abundant to take away the excess energy of the gas.

Kahn's paper raised almost more problems than it solved. Where, for example, do we observe these clouds in collision, when at any time five to 10 per cent of all clouds should be in collision? Or, should we take the cloud picture for the distribution of the interstellar gas less literally than has been done by Kahn and consider rather a general streaming of gas without so much emphasis on the discrete clouds?

Biermann and A. Schlueter, of Goettingen, have been investigating problems of radiation pressure and mass balance of the interstellar medium. They find that the pressure exerted by the H-II regions of low density between the discrete gas clouds exerts a stabilizing pressure on the embedded clouds of neutral hydrogen, the H-I regions. They argue further that the cirrus-like emission features are brought about by magnetic fields in the galaxy. Biermann, after a special study of the mass balance in the interstellar medium, makes the challenging suggestion that corpuscular radiation of all sorts from the stars each year returns the equivalent of one to 10 solar masses to the interstellar gas, thus possibly counterbalancing the loss of mass from the gas through accretion into stars.

Almost a day was spent on problems relating to accretion, by which we mean the growth of a star or condensation at the expense of the surrounding medium. The subject was introduced by W. H. McCrea, of Cambridge, while F. Hoyle and H. Bondi, also of Cambridge, and T. Gold, of Herstmonceux, took part in the discussion. E. Schatzman, of Paris, presented some objections to the present theory of accretion. The consensus was that accretion probably plays a very small role in *O* and *B* stars, since their temperatures would produce sufficient radiation pressure to repel any particles or atoms falling toward the star. It was further agreed that accretion would take place on a big scale only if the velocity of the star or condensation were of the order of one kilometer per second or less. In consequence of these limitations, the process was found by Schatzman to be possibly an important one in a small interval of stellar masses.

On the final day, we had a lively discussion about the constancy of the ratio between the densities of interstellar gas and cosmic dust. M. P. Savedoff, of Leiden (and Rochester), believes we cannot decide the question from available observational evidence and that it must be argued on the basis of theory alone. He showed that for reasonable gas densities the dust particles will be forced to move with the gas, and hence the ratio of their densities should be nearly the same for different parts of the galaxy and for dense and rarefied regions. He concluded that local regions of dense cosmic dust (globules, for example) also represent in all probability strong concentrations of interstellar gas.

The writer took the opposite stand;

FACING PICTURE: NGC 6334, toward the lower right, is the largest and brightest of this group of nebulosities photographed by M. J. Bester with the Harvard 60-inch reflector at Bloemfontein, South Africa, on a red-sensitive plate exposed one hour without a filter. Sir John Herschel discovered NGC 6334 visually with an 18-inch reflector in 1837, but failed to detect any of the other patches. Other photographs of this group, by Duncan with the 100-inch Mount Wilson reflector and the 18-inch Palomar Schmidt, appeared in "The Sky" for November, 1940. East is at the top.

The bright and dark nebulosities that form NGC 6188 in Ara resemble strongly the better-known Horsehead nebula near Zeta Orionis (of which a 200-inch photograph appeared on the August, 1951, back cover). The bright rim is possibly the heated, compressed zone between two cosmic clouds in collision. This photograph was taken on a 103a-E plate, exposed for 90 minutes by M. J. Bester with Harvard Observatory's 60-inch reflector at Bloemfontein. The position is 16^h 38^m, —48°.0 (1950). North is at the top.

close examination of photographs of different sections of the Milky Way indicates apparently very different conditions from one section to the next. In Carina, for example, the gas seems to be much more prevalent relative to the dust than in Sagittarius-Scorpius. In one section (directly east of the southern Coalsack) the *O* and *B* stars and the dust are conspicuous while there is no evidence for the presence of gas. There is no marked correlation between the amount of space reddening and the strength of interstellar absorption lines for highly reddened stars (other than the obvious correlation of both with distance of the star). This fact and the limited evidence available from 21-cm. observations in clear and obscured regions seem to argue against a uniformly identical relative distribution of gas and dust.

Summarizing our knowledge as it appeared at Cambridge, we seem to be well on the way toward understanding the important processes of the equilibrium of clouds of gas and dust. We are still, however, very far removed from a unified theory, and we are only just starting to explore the long-range evolutionary processes related to star formation.

The Jodrell Bank Symposium on Radio Astronomy

AT JODRELL BANK, about 50 astronomers and radio physicists, including most of the British radio astronomers, gathered from July 13th to 15th. There was a large delegation from Holland, as well as representatives from Australia, Finland, France, Germany, and the United States.

The variety of research at Jodrell Bank is great, and was described by the director of the station, Dr. A. C. B. Lovell, in this magazine in February and March, 1953. Another principal radio observatory is at Sydney, Australia; a gathering held there in August, 1952, was reported by F. J. Kerr, *Sky and Telescope*, January, 1953. Consequently, the present writer's account will concern only some of the more recent developments in radio astronomy.

The present large mast that carries the dipole of the 220-foot fixed receiver at Jodrell Bank is being replaced by a more rigid one, which will move with ease and certainty within the range of 10 degrees or so permitted by the fixed position of the receiver. Interesting as this existing equipment may be, however, the real object of attention is the 250-foot steerable radio telescope now under construction. The concrete base and central column are already well advanced; 2,500 tons of concrete have been poured, and one has only to walk around the base track under construction to appreciate the tremendous size of the instrument. According to present expectations, the steel work will be completed next summer and the basic frame will be up by September, 1954; operation may begin sometime in 1955.

Among the 30 papers presented, I was most impressed with those relating to discrete radio sources. R. Hanbury Brown and C. Hazard, with the 220-foot fixed paraboloid at 189 centimeters, have measured accurate radio magnitudes for several galactic and extragalactic sources. Their work seems to support the contention of B. Y. Mills, of Australia, that there are two varieties of discrete sources, one with large galactic concentration, the other with little or no galactic concentration. R. C. Jennison, of Jodrell Bank, finds that Cygnus A is probably a multiple source, with a simple double source fitting the observations fairly well. The very bright Cassiopeia A appears on the other hand to be roughly circular. Similar studies by Baldwin, of Cambridge, indicate diameters of five and three minutes of arc, respectively, for Cassiopeia A and Cygnus A, while Taurus A (identical in position with the Crab nebula) is in all probability slightly asymmetric.

At the Cavendish Laboratory, under the direction of M. Ryle, exciting research is being carried on with a large new interferometer system that permits the detection and measurement of the positions of even very faint discrete sources. The interferometer consists of four large units, each a radio "mirror" in the shape of a cylindrical paraboloid, made simply by stretching horizontal wires between vertical arcs of parabolas and with one line of detecting dipoles for each mirror. The four units, each about 100 meters long, have been mounted in pairs 60 meters apart, with the separation between the pairs about 600 meters. The units are oriented north-south and east-west, and the paraboloids may be rotated to various zones of declination.

The symposium on radio astronomy at Jodrell Bank Experimental Station, near Manchester, England, July 13-15, 1953.

KEY TO PHOTOGRAPH

Left to right, front row, Smith, Becker, Ryle, van de Hulst, Kourganoff, Biermann, Lovell, Tuominen, Laffineur, Minkowski, Bok, and Oort; *second row*, Bullough, Hanbury Brown, Neubauer, Hutley, Savedoff, Denisse, Koster, Seeger, Hey, Stumpers, Westerhout, Palmer, Kahn, and Storey; *last row*, Das Gupta, Gill, Kaiser, Hargreaves, Baldwin, Scheuer, O'Brien, Adgie, Williams, Shakeshaft, Davies (occulted), Schrader, Fokker, Schmidt, Little, Hill, Hazard, Jennison, Thompson, Maxwell, Dagg, and Browne.

For the larger sources the precision of position is about one minute of arc in right ascension and six minutes in declination; for the fainter sources it is not less than three and 20 minutes, respectively.

With the new equipment, Shakeshaft reported that in the zone of declination between 27° and 37° north, 120 discrete sources were plotted, and there must be altogether at least 170 detectable sources. Upon being questioned, Ryle refused to "count his sources before they are hatched," but a rough preliminary estimate indicates that the Cambridge equipment will record at least 500 of these sources and possibly 1,000!

The exact positions found by F. G. Smith at Cambridge for Cassiopeia A and Cygnus A have proved basic for the first identification of radio sources with galactic and extragalactic objects. From Mount Wilson and Palomar, Minkowski presented a progress report on this subject. The identification of Taurus A with the Crab nebula and of Cygnus A with two faint colliding galaxies has already been described in previous articles.

In the position of Cassiopeia A, the Palomar Schmidt plates reveal remarkable "scratchy" filaments of emission nebulosity, of a variety not observed eleswhere in the sky with the possible exception of a region in Puppis, from which strong radio radiation also comes. These scratchy filaments have internal radial velocities of the order of 3,000 kilometers per second. Minkowski suggested that such filaments may also be found near Cygnus X, the second strongest source in that constellation. He reported on several other identifications with extragalactic objects; where the identifications seem reasonably certain, special disturbances are observed, such as the jetlike stream shooting out of the nucleus of the galaxy M87.

Hanbury Brown has recently attempted to construct a radio model of our galaxy. It appears that at a wave length of a few meters the radio radiation is produced mostly by unknown sources with a galactic distribution resembling that of Population II stars and other objects. There is, probably, an additional contribution from free-free transitions originating in regions with ionized hydrogen, but it is very unlikely that this is the major source, in view of the lack of galactic concentration.

P. Scheuer, of the Cavendish Laboratory, has recently made an interferometric study to detect radiation from the narrow layer of ionized hydrogen clouds that lies close to the galactic plane. The expected energy from free-free transitions appears as a small but very definite peak superposed on the broad pattern of the general radiation.

G. G. Little, with the equipment now in operation at Jodrell Bank, was unable to detect the radiation at a frequency of 177 megacycles per second emitted by the second excited state of neutral hydrogen, which produces the 21-cm. line in its first excited state.

New equipment and plans for improvements in existing equipment were talked about continuously during the symposium. The Leiden group is building equipment for their new 75-foot steerable antenna, and other 21-cm. apparatus is being planned in Germany and Great Britain. The writer reported for Harvard Observatory on the 25-foot antenna that we have recently put into operation at our Agassiz station in Massachusetts.

The symposium demonstrated that the vigorous young science of radio astronomy bears watching. The forceful and intelligent approach by radio astronomers is changing the face of astronomy.

CORRECTIONS

The group photograph on page 13 of the November **Sky and Telescope** was taken by G. Haro and not by Bart J. Bok. On the next to the last line of the same page, for **supergiants** read **giants.**

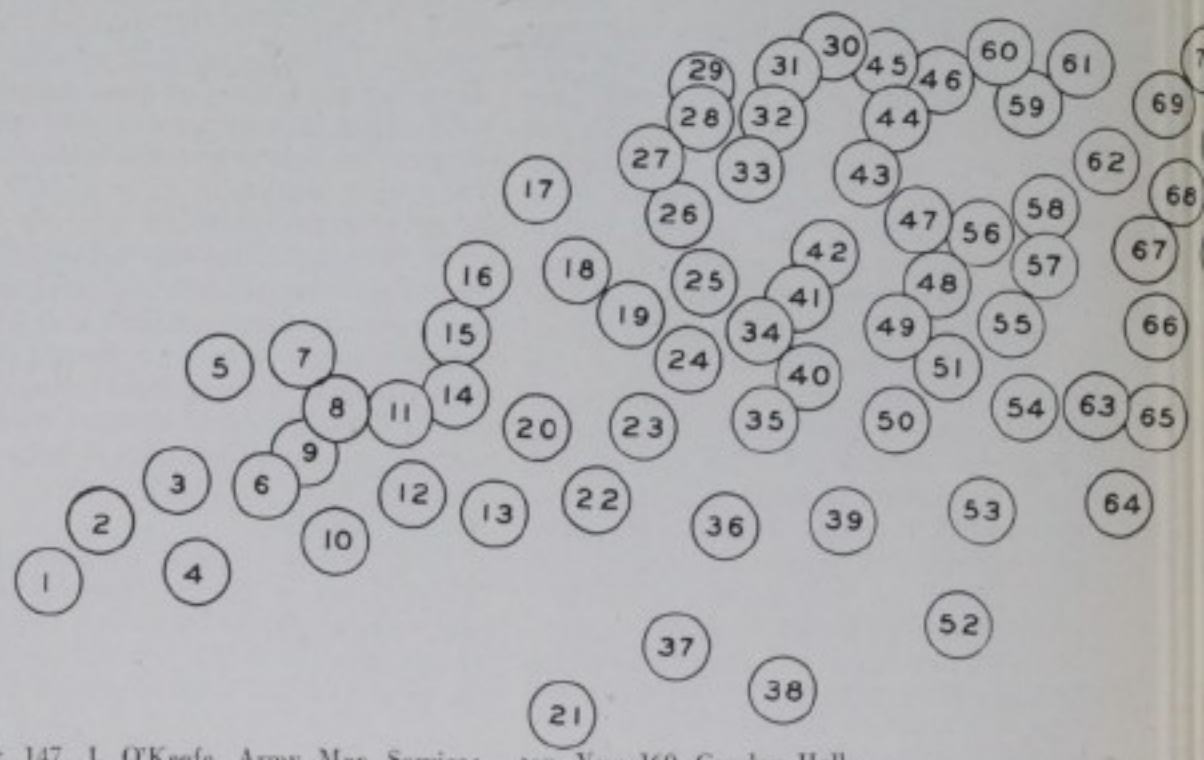
HIGH-SPEED PHOTOGRAPHY

A camera that can take pictures at the rate of 3½ million per second (170 exposures in 1/20,000 second) has been designed by Berlyn Brixner, at the Los Alamos Scientific Laboratory, for the purpose of studying high-explosive phenomena. According to *Physics Today* the pictures are taken by means of a mirror rotating 10,000 times a second, on film slightly larger than ordinary 16-millimeter.

Meanwhile, at the University of Rochester, Dr. Brian O'Brien has achieved the shortest exposure, 10^{-7} second, with cameras operating at faster than one million frames per second. He finds a new reciprocity law failure that is theoretically unexplained at present.

The reciprocity law in photography states that the density of a developed image is proportional to exposure time and light intensity. This law fails for very short or long exposures, but this failure could be explained by existing photographic theory even for the shortest previous exposures, 10^{-6} second.

Photograph by Floyd G. Walters.



KEY TO PHOTOGRAPH

1, Mrs. K. Virnelson, HA; 2, W. Andrews, HA; 3, Fr. F. Bertiau, Louvain, Belgium; 4, D. Harris, III, Ye; 5, F. Roach, NOTS; 6, J. Nassau, Warner and Swasey; 7, Mrs. G. McVittie; 8, M. Schwarzschild, Pr; 9, Mrs. R. Baker; 10, W. Roberts, HA; 11, L. Larmore, Rand Corp.; 12, E. Martz, Jr., White Sands; 13, Mrs. K. Henize; 14, S. Gaposchkin, H; 15, Mrs. C. Payne-Gaposchkin, H; 16, E. Yowell, Bureau of Standards, Los Angeles; 17, W. Baum, MWP; 18, J. Merrill, P; 19, G. McVittie, Illinois; 20, Mrs. K. Kron, L.

21, Alden Tombaugh; 22, K. Henize, M; 23, Mrs. L. Davis; 24, E. Weston, David Dunlap; 25, John Merrill; 26, R. Lee, Boulder, Colo.; 27, Mrs. G. Keller; 28, Miss S. Hill, Whitin; 29, Mrs. S. Chandrasekhar; 30, S. Chandrasekhar, Ye; 31, Jim Anderson; 32, G. Keller, P; 33, V. Goedicke, Ohio Univ.; 34, O. Heckmann, Hamburg-Bergedorf, Germany; 35, L. Davis, Caltech; 36, G. Van Biesbroeck, Ye; 37, George Greenstein; 38, Peter Greenstein; 39, Mrs. J. Greenstein; 40, P. Keenan, P.

41, Laura-May Merrill; 42, D. Billings, HA; 43, P. Annear, Burrell; 44, W. White, NOTS; 45, C. Anderson, Burlingame, Calif.; 46, E. Fath, Denver, Colo.; 47, J. Wolbach, H; 48, Mrs. J. Merrill; 49, L. Aller, M; 50, J. Greenstein, MWP; 51, P. Wellmann, David Dunlap; 52, Annette Tombaugh; 53, K. Strand, Dearborn; 54, R. Grenchik, I; 55, S. Thorndike, College of Emporia, Kan.; 56, P. Lindblad, Stockholm Observatory, Sweden; 57, E. Carpenter, Steward; 58, Miss B. Bell, H; 59, J. Irwin, I; 60, P. Riggs, Drake.

61, H. Arp, MWP; 62, G. Mulders, ONR, San Francisco; 63, Peter Goedicke; 64, E. Woolard, N; 65, C. Perry, I; 66, G. Kuiper, Ye; 67, C. Tombaugh, White Sands; 68, A. Cox, I; 69, A. Meinel, Ye; 70, Horace Babcock, MWP; 71, J. Stebbins, L; 72, G. Dimitroff, Dartmouth; 73, Miss H. Pillans, Cal; 74, Edward Kiess; 75, C. Kiess, Bureau of Standards; 76, Mrs. C. Kiess; 77, F. Kameny, H; 78, M. Walker, MWP; 79, John Dimitroff; 80, P. Mutschlecner, I.

81, L. Robinson, Wright-Patterson Air Base; 82, R. McCroskey, H; 83, B. Bok, H; 84, R. Brownlee, I; 85, Barbara Dimitroff; 86, Mrs. G. Dimitroff; 87, Miss L. Lowen, MWP; 88, H. Abt, L; 89, Mrs. K. Wright; 90, Mrs. A. Joy; 91, R. McMath, McM; 92, Mrs. W. Roberts; 93, Mrs. H. Federer, H; 94, D. Popper, Cal; 95, Miss J. Streeter, ONR, Washington, D. C.; 96, T. Bartlett, Chamberlin; 97, K. Wright, Dominion Astrophysical; 98, G. Grant, M; 99, R. Dunn, SP; 100, J. Hagen, NRL.

101, C. Whitney, H; 102, Mrs. J. Evans; 103, J. Evans, SP; 104, W. Miller, RCA Laboratories; 105, Mrs. J. Rush; 106, D. Brouwer, Yale; 107, Miss R. Jones, Watson Computing Bureau; 108, J. Rush, HA; 109, E. Spiegel, M; 110, Mrs. J. Stephens, Washington Univ., St. Louis; 111, Mrs. C. Tombaugh; 112, A. Joy, MWP; 113, A. Stephens, St. Louis; 114, A. Skumanich, Pr; 115, C. Federer, H; 116, L. Doherty, M; 117, R. Baker, Claremont, Calif.; 118, G. Muench, MWP; 119, Miss R. Hedeman, M; 120, C. Seyfert, Vanderbilt.

121, L. Green, Haverford; 122, R. Stoy, Royal Observatory, Cape of Good Hope; 123, D. Layzer, H; 124, J. Cuffey, I; 125, S. Boothroyd, Ithaca, N.Y.; 126, J. Milligan, M; 127, Mrs. K. Franklin, Leuschner; 128, Mrs. R. McMath; 129, K. Franklin, Leuschner; 130, Miss H. Dodson, McM; 131, A. Cook, H; 132, I. Epstein, Rutherfurd; 133, Mrs. U. Van Wijk; 134, A. Hogg, Mt. Stromlo, Australia; 135, A. Recht, Chamberlin; 136, Mrs. R. Young; 137, U. Van Wijk, Pr; 138, I. Greenbaum, N; 139, S. Milford, St. Johns Univ.; 140, Mrs. F. Edmondson.

141, G. Herzberg, National Research Council of Canada; 142, P. Herget, Cincinnati; 143, W. Markowitz, N; 144, Miss F. Wright, H; 145, Mrs. S. Boothroyd; 146, Stephanie Hoag; 147, J. O'Keefe, Army Map Service; 148, R. Rhynsburger, N; 149, G. Clemence, N; 150, F. Edmondson, I; 151, G. Reaves, Southern California; 152, D. Liebenberg, Wisconsin; 153, R. Young, Hughes Research Development Labs; 154, J. Roesch, Pic du Midi, France; 155, T. Matthews, H; 156, A. Sandage, MWP; 157, Miss E. Mueller, M; 158, Miss B. Turner, Cal; 159, D. Aronson, Arlington, Va.; 160, Carolyn Hall.

161, K. Yoss, Louisiana State; 162, E. Slipher, Lo; 163, R. Lynds, Cal; 164, G. Miczaika, L; 165, Mrs. R. Thomas; 166, T. Dunham, Rochester, N. Y.; 167, C. Athay, HA; 168, R. Cook, HA; 169, H. Johnson, Lo; 170, W. Livingston, MWP; 171, A. Wilson, Lo; 172, F. Pearson, HA; 173, D. Vrabec, M; 174, G. Kron, L; 175, R. Thomas,

H; 176, A. Linnell, Amherst; 177, Z. Kopal, Univ. of Manchester, England; 178, J. Hall, N; 179, Sir H. Spencer Jones, Royal Greenwich Observatory, England; 180, J. Gleim, N.

181, W. Rense, Colorado; 182, D. Guthrie, Louisiana State; 183, Mrs. J. Hall; 184, Mrs. G. Clemence; 185, S. Matsushima, H; 186, F. Whipple, H; 187, Mrs. C. Warwick, SP; 188, Miss M. Risley, Randolph-Macon; 189, Miss L. Jenkins, Yale; 190, Mrs. D. Menzel; 191, Mrs. C. Huffer; 192, F. Wood, Flower and Cook; 193, Mrs. A. Hoag; 194, A. Hoag, N; 195, Tommy Hoag; 196, O. Mohler, McM; 197, W. Hiltner, Ye; 198, C. Huffer, Washburn; 199, D. Menzel, H; 200, Miss H. Jenkins, New Haven, Conn.

201, G. Newkirk, SP; 202, J. Warwick, SP; 203, Mrs. F. Whipple; 204, T. Hatanaka, Cornell and Tokyo, Japan; 205, Richard Hall; 206, Mrs. P. Herget.

Cal, University of California; H, Harvard; HA, High Altitude Observatory; I, Indiana; L, Lick; Lo, Lowell; M, Michigan; McM, McMath-Hulbert; MWP, Mount Wilson-Palomar; N, Naval Observatory; NOTS, Naval Ordnance Test Station; NRL, Naval Research Laboratory; ONR, Office of Naval Research; P, Perkins; Pr, Princeton; SP, Sacramento Peak; Ye, Yerkes-McDonald,

American Astronomers Report

Here are highlights of some papers presented at the 89th meeting of the American Astronomical Society at Boulder, Colo., in August. Complete abstracts will appear in the Astronomical Journal.

Photography of Mars

E. P. Martz, Jr., of White Sands Proving Ground, reported on extensive photographic observations of Mars during the 1937 and 1939 oppositions. A total of 3,600 images was secured with the Mount Wilson 60-inch reflector and 6-inch refractor, the 12-inch Griffith Observatory refractor, and the 36-inch reflector of the Steward Observatory at Tucson, Ariz. Red, yellow, green, and blue-violet color filters were used, giving effective wave lengths of 6500, 5600, 5300, and 4400 angstrom units, respectively.

Nearly simultaneous exposures in different colors confirmed and extended the earlier results by W. H. Wright, E. C. Slipher, and others. Like them, Mr. Martz found the surface markings are most distinct at longer wave lengths. Observations of obscuring clouds showed that while these are ordinarily brightest against the disk in blue-violet light, there are some types of clouds with maximum brightness in the green part of the spectrum.

The over-all blue-violet reflecting haze generally rendered the surface markings indistinct or invisible, but noteworthy variations in the amount of this veiling occurred, especially in 1939. Some terrestrial photographs were taken for photometric comparison, which demonstrated that the ordinary blue-violet obscuration in the Martian atmosphere is about the same as in a horizontal air path of 20 to 30 miles in the earth's atmosphere, at an elevation of 2,400 feet in a desert climate.

Although Mr. Martz' primary purpose was the study of the Martian atmosphere, his photographs contain much information on the surface features. The small 6-inch refractor showed a surprising amount of detail, and even features like Thoth-Nepenthes. The best of the photographs, from the point of view of surface markings, were obtained with the 36-inch reflector with an eccentrically located 12-inch diaphragm, working at an effective focal length of 100 feet, and an exposure time of 1/25 second. As he remarked, "It is clear that large apertures are not necessarily a prerequisite for such photography."

New Class of Variable Star

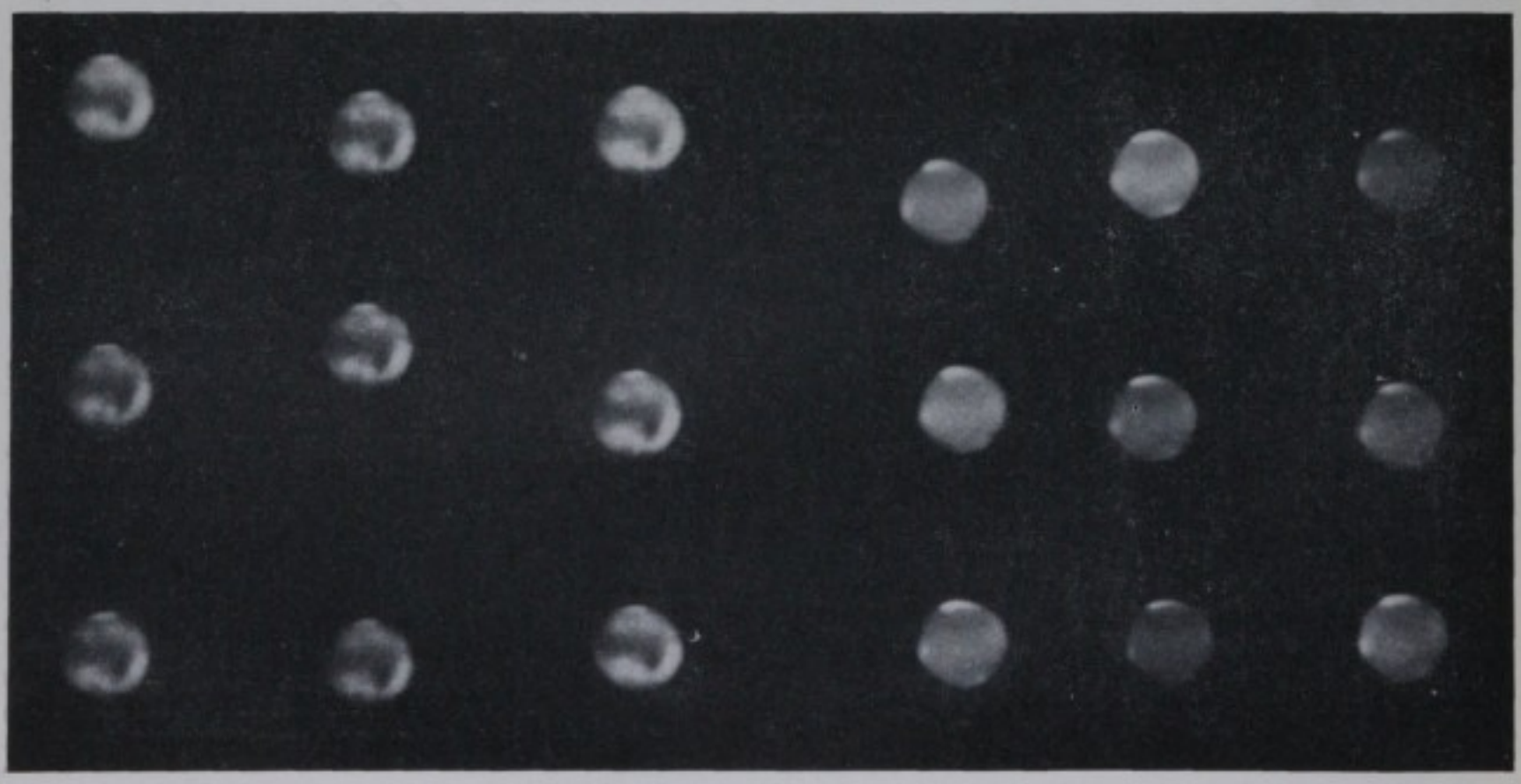
According to Drs. E. P. Hubble and A. R. Sandage, Mount Wilson and Palomar Observatories, the five brightest irregular variables in the nearby galaxies M31 and M33 share uncommon properties which place them in a previously unrecognized class of variable stars. These variables are very luminous blue stars with spectra of type *F*.

The most significant fact about the five variables is that at maximum light they all have very nearly the same photographic absolute magnitude, −8.4, when Baade's provisional correction to the cosmic distance scale is taken into account. If this small dispersion in intrinsic luminosity is confirmed, this kind of variable will be useful as an indicator of the distances of galaxies.

Proposed Observations of Mars

No relief map of Mars has yet been made, but it has often been suggested that the reddish areas are high ground and the greenish maria are depressed regions. The first such map may result from observations to be made during the favorable oppositions of 1954 and 1956, following a method proposed by Clyde W. Tombaugh, of White Sands Proving Ground. He recommends that the intensity of the weak carbon dioxide bands in the infrared spectrum of Mars be measured over different regions of the planet's surface. These bands should be stronger over low-lying areas, which would be seen through a greater thickness of the Martian atmosphere.

Two other projects proposed by Mr. Tombaugh are the spectroscopic detection of water vapor and of chlorophyll,



These pictures of Mars were made in 1939 with the 36-inch reflector of the Steward Observatory; the exposures were in rapid succession, in red light (left) and blue-violet light (right). The south polar cap (at the top of each image) is conspicuous in both colors, but the dark surface markings are effaced in blue-violet. The very dark feature below the center of the disk is Syrtis Major. Notice the conspicuous Martian cloud on the blue-violet photographs, on the left margin of the planet. Photographs by E. P. Martz, Jr.

by taking advantage of the most favorable Martian seasons for their occurrence.

Several practical suggestions to students of Mars were offered by Mr. Tombaugh. Visual observers should use a magnification of at least 30 per inch of aperture, and a yellow or amber filter will increase the contrast between the red and green surface features. He strongly recommends that eccentrically placed circular diaphragms be used on large reflecting telescopes for either visual or photographic work, as this considerably sharpens fine surface detail.

Globular Cluster M3

Dr. Allan R. Sandage, Mount Wilson and Palomar Observatories, used 200-inch reflector plates to complete a count of 44,500 stars brighter than photovisual magnitude 22.5, within eight minutes of arc of the center of the globular cluster M3. The photovisual absolute magnitude of the faintest stars counted is +6.9. Stars brighter than absolute magnitude +3.8 account for 90 per cent of the total light of the cluster, but contribute only a small fraction of the total mass, which Dr. Sandage estimates to be 140,000 times that of the sun.

A study of the evolutionary development of the stars in M3 has been made on the basis of the Schoenberg-Chandrasekhar theory. This shows that the present giant members of the cluster (brighter than absolute bolometric magnitude +3.5) have originated in a very small segment of the main sequence extending from absolute bolometric magnitude +3.94 to +4.50. If the supposed evolutionary tracks are correct, all these giant stars in M3 should have masses equal to about 1.2 solar masses.

Radio Observations of the Magellanic Clouds

The Magellanic Clouds, being the two nearest known galaxies, are sufficiently close to us so that their internal structure can be studied by both optical and radio techniques. Two Australian radio astronomers, F. J. Kerr and J. V. Hindman, of the Radiophysics Laboratory, Sydney, have measured the 21-cm. line radiation from neutral hydrogen for about 250 points within both clouds, using a 36-foot antenna. It was previously known that the Large Magellanic Cloud contained much absorbing dust, and the Small Cloud practically none. But since the radio observations show that both clouds contain about the same amount of neutral hydrogen, it follows that the ratio of gas to dust is very different in the two systems.

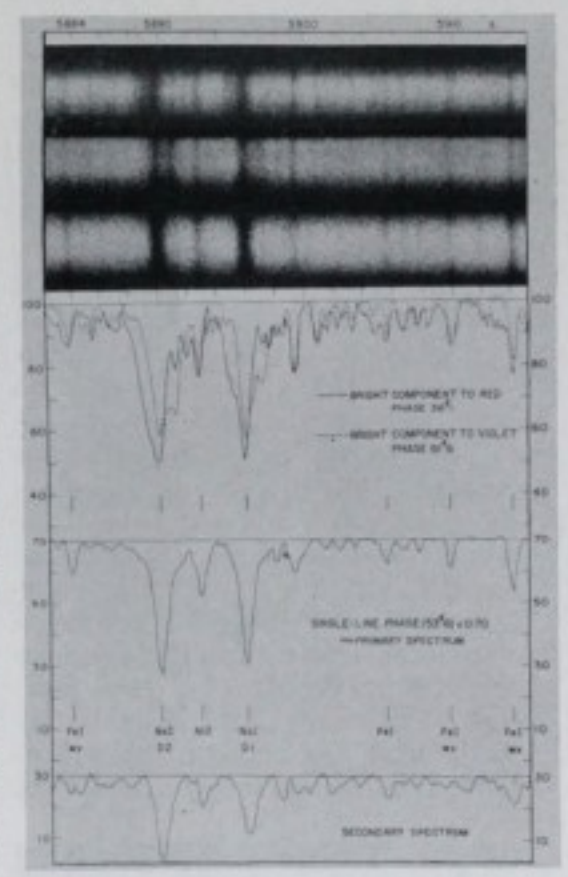
The distribution of the gas is notably different in the two clouds. In the Large Cloud, this distribution is similar to that of the stars, but the Small Cloud has an envelope of gas extending well outside the central core of stars.

The radial velocities of the two clouds, as determined from the 21-cm. hydrogen line, indicate that they form a binary system.

Spectrum of Capella

The apparently well-understood spectroscopic binary star Capella was found to present many puzzles when Otto Struve studied its spectrum with high dispersion a few years ago (*Sky and Telescope*, April, 1951). The principal features are that a number of strong lines to be expected from the brighter *G*-type component are apparently absent; many of the expected lines of the fainter *F*-type star are not seen; and the *F* lines dominate in the violet end of the spectrum, while the *G* lines dominate at the red end.

Two reports on the problem of Capella were offered, by Dr. K. O. Wright, of the Dominion Astrophysical Observatory, and by K. L. Franklin, of the University of California. Dr. Wright found that it was possible to disentangle the spectrum of the fainter star from that of the brighter, by comparing densitometer tracings of spectra observed when the lines were doubled with tracings when the lines were superimposed, as shown in the accompanying illustration. In this way it was found that the spectral types of the primary and secondary components are about *G*2 II, and *F*8 II or III, respectively. From the radial velocities the ratio of masses of the *G* and *F* stars was found to be 1.03 ±0.09.



These three spectra of Capella are typical of those used by K. O. Wright in his analysis. The period of this binary is 104 days. The region of the D lines of sodium is shown. The F star was approaching us, 36.1 days after it passed behind the bright G star, when the top spectrum was made; therefore its spectral lines are shifted violetward (left). In the second spectrum, 81.6 days after conjunction, the F star was receding, and its lines are shifted to the red (right). The uppermost diagram shows the tracings from these two spectra. In the lowest spectrum the lines of the components are superimposed, 53.6 days after conjunction, and its tracing is the middle one. The lowest diagram is the deduced spectrum of the F star. Dominion Astrophysical Observatory photograph.

At the Mount Wilson Observatory, Mr. Franklin scanned the spectrum of Capella photoelectrically and compared the energy curve obtained with that of other stars. He found that the two components differ only slightly in both brightness and spectral type, as inferred from the continuous spectrum. Consequently, either the energy distribution of a normal late *F* giant star resembles that of a normal early *G* giant, or the fainter *F* component of Capella is abnormally red for its spectral type.

Photometric Studies of Distant Galaxies

A photon-counting photometer has recently been put into operation as an accessory to the 200-inch Hale telescope. Instead of recording the rate of electric current flow created by the light of a star or galaxy, this instrument counts the units of light energy, or photons, that are received at the focus of the instrument. The device has already shown that the photographic limit of the 200-inch is magnitude 23.5, half a magnitude fainter than was previously estimated.

Dr. William A. Baum, Mount Wilson and Palomar Observatories, described the first results obtained with this photometer on very distant galaxies. He has measured their apparent brightnesses and apparent diameters simultaneously, in order to estimate their distances. On the assumption that galaxies with similar characteristics have an average size and brightness, we can estimate the distance of any one galaxy from its apparent luminosity and size.

Dr. Baum finds that the faint outer regions of a galaxy make a greater contribution to its total light than has previously been realized, and the tendency to make less-inclusive measurements of nearby galaxies has introduced a sizable error into earlier work, with corresponding inaccuracies in distance estimates for more distant systems.

By fitting his results into the equations of general relativity, Dr. Baum expects to distinguish the effects of changes of age in the galaxies themselves, and possible absorption by intergalactic obscuring matter, from observable characteristics that result from the great distances involved and from the expansion of the universe.

NEWS NOTES

By Dorrit Hoffleit

MAGNETIC FIELDS IN SPIRAL ARMS

Measurements of the polarization of light from distant stars have in recent years given support to a theory by Dr. E. Fermi of the existence of a magnetic field in the galaxy. The polarization is presumed due to the orientation of elongated dust particles by the magnetic field, in which case the observations should show no polarization in a direction parallel to the magnetic lines of force and maximum polarization in directions perpendicular to the lines of force. On this theory it has been found that the magnetic lines of force extend along the direction of the spiral arm through the sun.

Starting with these concepts, Drs. S. Chandrasekhar and Fermi, both from the University of Chicago, attempt in the *Astrophysical Journal* to estimate the strength of the interstellar magnetic field. They adopt two methods. In the first (originally applied to less accurate data by Leverett Davis, Jr.), they consider the dispersion in the observed planes of polarization of the light of distant stars. The second method is based on the requirement that the spiral arm be stable with respect to lateral expansion and contraction. The first method yields a value of 7.2 millionths of a gauss, the second, six millionths. The two determinations are in good agreement. However, they indicate a field strength about 10 times weaker than Greenstein and Davis in 1951 had estimated as necessary for aligning the dust particles adequately to account for the observed polarization.

ROTATION PERIOD OF MARS

Considering the great interest in the planet Mars, it is surprising that since 1886 no one had made a definitive determination of its rotation period until Dr. Joseph Ashbrook published a new value in the August issue of the *Astronomical Journal*. While at Yale University Observatory, he worked over a considerable amount of observational material, and excluded old drawings of the planet as of insufficient accuracy. From modern observations, principally central meridian transits of 1877-1952, he finds the Martian day to be $24^h\ 37^m\ 22^s.6679$, a value only $0^s.014$ longer than the figure long used in the *American Ephemeris*, but with 25 times greater weight.

Since Mars is the only other planet whose rotation period can be accurately measured, Dr. Ashbrook was interested in whether or not Mars, like the earth, has measurable changes in rotation. Dr. Dirk Brouwer, at Yale, had found that the earth's day was $0^s.0064$ longer in the decade 1901-1910 than in the decade 1866-1875. The mean error of the new determination of the Martian day is only $0^s.0026$. Hence, Dr. Ashbrook concludes, the possibility of examining Mars for analogous changes in rotation is not remote. Advantage should be taken of the coming favorable oppositions of the red planet for accurate observations of the positions of well-known markings.

TWO KINDS OF RR LYRAE VARIABLES

Several years ago it was conclusively established that the classical Cepheid variables (pulsating stars with periods from about one to 100 days) can be separated into two categories: ordinary Cepheids belonging to Population I, and W Virginis-type Cepheids belonging to Population II. In a recent publication from Torun, Poland, Dr. Wilhelmina Iwanowska now finds a similar segregation of the cluster-type or RR Lyrae variables (pulsating stars with periods shorter than a day). Dr. Iwanowska's spectroscopic investigation shows that their period-spectrum relation has two distinct sequences, one of which is evidently the extension of the corresponding relation for the Cepheids of Population I, the other of Population II.

The cluster-type variable star (HD 223065) with the shortest known period, 80 minutes, discovered by O. Eggen (*Sky and Telescope*, March, 1952), belongs to the Population I group. The period-luminosity curves for the two populations cross at periods of about a third of a day.

Dr. Iwanowska finds further that the spectra of these stars confirm previous indications that the stars of Population II are deficient in hydrogen compared with the Population I stars. Both groups of RR Lyrae stars, however, apparently have less hydrogen than nonvariable stars of the same spectral class.

The red dwarf star BD +43°4305, also known as Ci (20) 1382, was caught during a flare on October 1st, as it crossed the meridian during this sequence of parallax photographs. On the original plate the separation of the first and second images is one millimeter. Allegheny Observatory photograph, by Glenn Winterhalter.

IN THE CURRENT JOURNALS

WHY DO GALAXIES HAVE A SPIRAL FORM? by Cecilia H. Payne-Gaposchkin, **Scientific American,** September, 1953. "If we have analyzed the arms of galaxies correctly, they are fairly localized lanes of dust, which ride on atomic winds that blow about the galaxy with a rotational motion. But the theory of turbulence is at once powerful and treacherous, and its application to problems of galactic structure is still young."

AGE OF THE UNIVERSE

The need for more caution in statements concerning the age of the universe has recently been emphasized by Dr. G. C. McVittie, of the University of Illinois. Writing in the *Astronomical Journal*, he notices that there is considerable confusion in the minds of astronomers on how the general theory of relativity is to be used in such problems. He points out that the Hubble constant, as deduced from the red shifts of galaxies, is insufficient by itself to determine the age of the universe. Any age calculation requires additional unverifiable hypotheses. Different sets of hypotheses lead to widely different but equally plausible ages.

ATTILIO COLACEVICH

The death in August of Attilio Colacevich at the age of only 53 will be keenly felt, as leaving a serious gap in the ranks of outstanding Italian astronomers. A pupil of Dr. G. Abetti, director of the observatory at Arcetri-Firenze, Dr. Colacevich was expected in time to become his successor. The diversity of his astronomical interests is attested by his papers on solar and lunar eclipses, stellar kinematics, solar phenomena, and instrumentation.

FLARE STAR

Dr. N. E. Wagman, director of the Allegheny Observatory, has reported a flare of the star BD +43°4305 on October 1, 1953. The usual visual magnitude of the star, whose spectral type is d*M*5e, is 10.2. On that date, a photograph was taken with three exposures each of 4½ minutes. The first exposure showed the star normal, the second, a magnitude brighter, and the third, a magnitude still brighter. The 1950 position of the star is $22^h\ 44^m.7$, +44° 05′.

A portion of an enlargement from the original parallax plate is shown here. The first image at the left is of the flare star; it is also shown in the second and fourth images. Images 3 and 5 are of a fainter star, and there is another exposure of it that overlaps the second image of the flare star, but has little effect on the image. The actual observations were carried out by Glenn Winterhalter, vice-president of the Amateur Astronomers Association of Pittsburgh; the enlargement was made by Joseph Rachuba, another Pittsburgh amateur.

Amateur Astronomers

The Annual Meeting of the AAVSO

REPORTS of unabated observational activity by its members and discussion of problems of future organization characterized the annual meeting of the American Association of Variable Star Observers, held at Harvard Observatory, Cambridge, Mass., on October 9th and 10th.

During the preceding 12 months, the number of variable star observations accumulated by the AAVSO in its 42-year history passed the 1,500,000 mark. Mrs. Margaret W. Mayall, recorder, reported that more than 62,000 estimates were added by 144 observers. The most productive were Demetrius P. Elias, of Greece, who made 8,363 estimates, and Reginald P. de Kock, of South Africa, with 6,467 estimates. Special programs on peculiar variables were actively carried on. The photoelectric observations by John Ruiz deserve particular mention.

The auroral work of the AAVSO under the direction of D. S. Kimball is taking on increased importance. Despite the low level of solar activity in the past year, systematic observations of 11 auroral displays were made. Mr. Kimball, in co-operation with Prof. C. W. Gartlein, of Cornell, has studied the geographical extent of auroral displays, and the correlation between auroral and geomagnetic index numbers.

In recent years the Solar Division of the AAVSO has been enabled, by financial support from the National Bureau of Standards, to collect and analyze a large volume of solar observations, under the leadership of Neal J. Heines. Unfortunately, this aid ended in June, and the future of the association's solar work is still uncertain.

As in previous years, the highlight of the society dinner was the summary of the most significant developments in astronomy during the past year, presented by Dr. Harlow Shapley, of Harvard College Observatory.

Four of Dr. Shapley's 11 highlights dealt with observatories and equipment. These were progress toward the establishment of a national research observatory, probably to be in the Southwest; beginning of construction of the 250-foot steerable radio telescope at Jodrell Bank; the construction by Lallemand and his associates at Paris of an electronic telescope; and Baum's detection of 23rd-magnitude stars with a new photon-counting photometer attached to the 200-inch reflector.

Investigations of solar system objects accounted for four more highlights. The solar corona is much larger than its visible streamers indicate, as observations of the occultation of the Taurus radio star by the sun showed. Detection of the Lyman-alpha line in the far ultraviolet solar spectrum was accomplished by two groups of investigators, using instruments carried aloft by Aerobee rockets. The connection between the corona and the zodiacal light was demonstrated by Roach's studies of the light of the night sky. Light variations of 10 asteroids measured photoelectrically at the McDonald Observatory confirm the belief that these bodies are rapidly rotating irregular fragments.

Galaxies were the subject of the remaining three of Dr. Shapley's highlights. Much evidence has been collected confirming the revision of the extra-galactic distance scale. Kerr and Hindman's exploration by radio techniques of the Magellanic Clouds has provided important new insight into the structure and motions of these two nearby galaxies. Finally, McVittie's application of relativity to gas dynamics offers an important tool for the study of interstellar gas, which may have far-reaching significance.

KEY TO PHOTOGRAPH

From left to right: D. Rosebrugh, Mrs. E. Lundberg, E. Lundberg, A. Taboada, Miss A. Farnsworth, J. Ruiz, D. Kimball, F. Schmelzer, Miss J. Gill, R. Buckstaff, K. Weitzenhoffer, Mrs. R. Buckstaff, E. Oravec, R. Greenley, Mrs. R. Greenley.

W. Miller, Mrs. W. Miller, D. Taboada, J. Stokley, J. McCaig, J. Streeter, Miss H. Stephansky, Mrs. M. Carpenter, A. Ingalls (back), F. Jones, H. Chase, Miss D. Hoffleit, P. Witherell, B. Chester (back), R. Seely.

Miss M. Harwood, C. Smiley (back), N. Mayall, J. Gagan, C. Moulton, S. Zimmerman, C. Fernald, Mrs. H. Federer, L. Holloway, B. Cleveland, H. Paul, F. Reynolds, R. Chiabotta, J. Welch (back), R. Franklin.

R. Hamilton, R. Wright, A. Moulton, Mrs. M. Mayall, W. Reid, F. Marsh (back), G. DiDomenico, Mrs. W. Reeves, O. Gingerich, W. Reeves, S. Brower, C. Ford.

THIS MONTH'S MEETINGS

Buffalo, N. Y.: Buffalo Astronomical Association, 7:30 p.m., Museum of Science. Dec. 2, Dr. C. Furnas, Cornell Aeronautical Laboratories, "The Upper Atmosphere."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. Dec. 11, Dr. Helen W. Dodson, McMath-Hulbert Observatory, "The Sun — Extraterrestrial Laboratory and Nearest Star." Christmas party.

Dallas, Tex.: Texas Astronomical Society, 8 p.m., First National Bank. Dec. 28, Ted Gangl, "The Big Ball We Live On."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., Geneva Public Library. Dec. 8, John Sternig, Glencoe Public Schools, "Planet Mars." Christmas party.

Indianapolis, Ind.: Indiana Astronomical Society, 2:15 p.m., Cropsey Hall. Dec. 6, annual meeting, board of officers, "Review of 1953."

Lansing, Mich.: Lansing Amateur Astronomers, 8 p.m., No. 8 Fire Station. Dec. 17, Wesley Clark, "Northern Lights."

Madison, Wis.: Madison Astronomical Society, 8 p.m., Washburn Observatory. Dec. 9, Prof. Phillip S. Myers, University of Wisconsin, "Jet Propulsion."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Dec. 2, Dr. Fred L. Whipple, Harvard College Observatory, "The Earth's Atmosphere and Astroballistics."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Dec. 5, Dr. I. M. Levitt, Fels Planetarium, "The Human Body in Space."

NEWS ROUNDUP

The Texas Astronomical Society of Dallas, both senior and junior groups, again prepared an exhibit for the Texas state fair, held in October this year. At the society's seventh anniversary meeting, E. M. Brewer was re-elected presi-

The 42nd annual meeting of the American Association of Variable Star Observers, Cambridge, Mass., October 10, 1953.

What About Sunshine?

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52. Sunspot Classifications
53. The First Coronagraph
54. Reporting the Corona
55. Corona Punched Cards — 1
56. Corona Punched Cards — 2
57. The New Coronagraph — 1
58. The New Coronagraph — 2
59. A.A.V.S.O. Sunspot Counts
60. Daily Sunspots and Groups
61. Daily Sunspot Areas
62. Relative Monthly Sunspots — 202 years
63. Aurora Classifications
64. Aurora Cycles
65. Reporting the Aurora
66. Three North Poles
67. Sunspots and Other Cycles
68. Oil - Coal — or Perhaps Solar Heat
69. The Sun and Radio — 1
70. The Sun and Radio — 2
71. The Sun and Radio — 3
72. The Sun and Radio — 4
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dent; Ted F. Gangl and W. T. Vanderpool are vice-presidents; Mrs. Alice Peek, recording secretary; Rosabel Harris, corresponding secretary; E. T. Cramer, treasurer; and John Hulme, chairman of junior activities. There are now 70 senior members, and 36 juniors.

A new society has been formed as the Astronomy Section of the Peoria Academy of Science, which will meet the second Wednesday of each month at 8 o'clock in the Peoria Heights School. Construction of an observatory to house a 9-inch refractor is a current project of the group. Further information about the new society may be had from R. P. Van Zandt, its president, at 156 N. Eleanor Pl., Peoria 5, Ill.

The Amateur Telescope Makers Club of El Monte, Calif., has been active through 1953. Members have completed one 4-inch and two 6-inch telescopes, and are building nine others ranging from three to 10 inches in diameter. Meetings are held every second and fourth Wednesday evening at the home of Ray Cogswell, 3915 N. Cogswell Rd., El Monte, Calif. Membership is open to all interested in telescope making.

A program schedule for its entire 1953-54 season is one of the accomplishments of the Lansing Amateur Astronomers, following a reorganization which will also include expanded junior activities and a membership drive. Christine Culp is president; Rodney Shafley, vice-president, and Richard Stanish, 1019 E. Main St., Lansing, Mich., secretary-treasurer.

A START IN ECLIPSE PLANNING

(Continued from page 34)

ing at that time of year for most of the area. The table gives the data.

	Percentage of cloud, 7:30 EST					
	June			July		
	0-20	30-70	80-100	0-20	30-70	80-100
White River	28	9	63	33	16	51
Pagwa	20	13	67	21	20	59
Kapuskasing	17	16	67	24	17	59
Moosonee	21	10	69	28	16	56

	Av. no. days with fog		Av. no. days with measurable precip.	
	June	July	June	July
White River	1	4	13	12
Pagwa	3	3	13	15
Kapuskasing	3.5	5	13	14
Moosonee	2.5	3	12	10

It can be seen that these figures agree fairly well with and supplement the data given by Edward M. Brooks in "The Weather Outlook for Next Year's Eclipse," **Sky and Telescope,** October, 1953.

Since the weather, as predicted by Dr. Brooks, is more likely to be better in the United States, we investigated maps for that area. A valuable map was discovered which is published by the Northern Great Lakes Area Council, P. O. Box 5439, Chicago, Ill. This council is a joint effort of Michigan, Minnesota, Ontario, and Wisconsin to promote vacation and tourist trade in the region. The map consists of one sheet on which the whole area is plotted on a scale of about 40 miles to the inch. One side has a road map, while the other side has a conservation and recreation map showing parks, reservations, points of interest, and so on. The eclipse path can be plotted easily on this. Around the edges of the maps and as inserts are smaller maps showing air lines, railroads, bus lines, ferries, and so forth.

More detailed road maps and travel information are available from the following state bureaus: Michigan Tourist Council, 114 S. Walnut St., Lansing 15, Mich.; Wisconsin Conservation Dept., Recreational Information Section, 835 State Office Bldg., Madison 2, Wis.; and Minnesota Division of Publicity, Dept. NGL, State Capitol Bldg., St. Paul 1, Minn. Detailed U. S. topographic survey maps for planning an eclipse site can be obtained from the Geological Survey, Washington 25, D. C., for 20 cents per sheet. Outline maps of states from which to select individual sheets of small areas are available.

It would help, of course, to visit a proposed observing site well ahead of time to select an exact location that is high, flat enough to set up equipment, has an unobstructed view north and east at least, living quarters not too far away, electric power available, if necessary, and other special conditions as required by the observing program. In our case it will not be convenient to get to the area this year, so we expect to make the trip with time enough before eclipse day to select a site and set up equipment.

D. C. WHITMARSH
1152 S. Atherton St.
State College, Pa.

Sky Publications for Christmas

MAKING YOUR OWN TELESCOPE. by Allyn J. Thompson — This book gives complete instructions on how to make a 6-inch reflecting telescope **$4.00**

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BOOKS AND THE SKY

NEW GENERAL CATALOGUE OF NEBULAE AND CLUSTERS OF STARS

and Index Catalogue, Second Index Catalogue. J. L. E. Dreyer. Royal Astronomical Society, Burlington House, London, 1953. 378 pages. £3 10s.

WHAT the **Bonner Durchmusterung** and its southern extension is to the comprehensive presentation of the positions of stars brighter than magnitude 9.5, and the **Henry Draper Catalogue** is to the spectra of over 300,000 of these objects, so are the **New General Catalogue** and its supplements to the positions of some 10,000 of the brightest clusters and nebulae. These three compilations are necessities for the working astronomer, and the three designations, BD, HD, and NGC, will long be standard nomenclature for stars, nebulae, and galaxies.

There were some earlier listings of clusters and nebulae before J. L. E. Dreyer took over the field. For instance, there were the small catalogue by Messier and the great ones by the Herschels, especially the so-called **General Catalogue of Nebulae**, published by Sir John Herschel in 1864. Dr. Dreyer, director of the Armagh Observatory, started his serious cataloguing in 1876, when he compiled "for use in Lord Rosse's Observatory a complete list of corrections to the General Catalogue, as well as a catalogue of the nebulae discovered by D'Arrest, Marth, Stephan, Temple, and others."

In 1886 the council of the Royal Astronomical Society recommended to Dr. Dreyer that he amalgamate the preceding lists into a **New General Catalogue,** and in 1888 this standard work, based largely on the observations of the Herschels, was published by the Royal Astronomical Society. Seven years later the first **Index Catalogue,** containing 1,529 entries and supplementing the 7,840 of the NGC, was published by the same society, and in 1908 a **Second Index Catalogue** appeared, containing 3,857 entries. Objects in the index catalogues are designated IC.

The total number of objects included is therefore more than 13,000, but there are a few hundred false entries in the three — duplications and errors of observation, such as the mistaking of small groups of stars, and even of comets, for nebulae. Also, the **Second Index Catalogue** contains reports on some spotty deep surveys, photographic and otherwise, so that uniformity of sky coverage is no longer approached as it was with the first of the three publications.

The NGC and its supplements went out of print some years ago. It is therefore a boon to the increasing number of workers on clusters and galaxies, and to the amateur observer, that the Royal Astronomical Society has reprinted these catalogues by the photographic offset process. The type size is the same as the original, but the page size is somewhat smaller by reduction of the margins. The pagination has been changed, and it is now consecutive through the present single volume.

Those who have worked extensively in the general field will have their own copies profusely marked with corrections that have accumulated during the past 65 years. A number of these were already indicated in the indices, but of course in this present reproduction no further corrections have been entered.

It is quite possible that more extensive sky-covering catalogues will never be published in detail. There are too many galaxies, just as there are too many stars in the Milky Way for a systematic extension of the **Bonner Durchmusterung** to magnitude 12 and fainter. A single photographic plate made with a large Schmidt telescope sometimes records more galaxies than the total of Dreyer's catalogues. We do not care to know the individual positions, magnitudes, and forms of these abundant individuals; but we shall long want to know for the brighter galaxies, clusters, and nebulosities, the things that this new reprint of the classic catalogue will provide us.

HARLOW SHAPLEY
Harvard College Observatory

NEW BOOKS RECEIVED

THE RED AND GREEN PLANET, *Hubertus Strughold*, 1953, *University of New Mexico Press.* 107 pages. $4.00.

Dr. Strughold was formerly professor of physiology at Heidelberg and is now with the Air Force School of Aviation Medicine at Randolph Field. He discusses from the viewpoint of a physiologist the possibility of life on Mars.

CATALOG OF 5,268 STANDARD STARS, 1950.0, BASED ON THE NORMAL SYSTEM N30, *H. R. Morgan*, 1952, *U. S. Government Printing Office.* 241 pages. $2.25.

Prof. Morgan's catalogue forms Vol. 13, Part 3, of the *Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac.* It contains precise positions of standard stars, mostly visible to the naked eye, from a combination of over 70 recent catalogues, both northern and southern. The new fundamental system of star places thus defined is the N30 system. Extensive tables are given which show its relation to the earlier FK3 and GC fundamental systems.

ERDROTATION, MONDBEWEGUNG UND DAS ZEITPROBLEM DER ASTRONOMIE, *F. Gondolatsch*, 1953, *G. Braun GmbH*, Karlsruhe, Germany. 44 pages. DM 6.

"The Earth's Rotation, the Motion of the Moon, and the Time Problem in Astronomy," as the title may be translated, is Publication No. 5 of the Astronomisches Rechen-Institut. It is a comprehensive survey of the irregularities in the earth's rotation period, and of the resulting apparent irregularities in the moon's motion. The author stresses the desirability of observing occultations of stars by the moon, and explains in detail how to reduce such observations. There is a bibliography listing 79 references.

SCIENCE IN PROGRESS, 8TH SERIES, *George A. Baitsell*, editor, 1953, *Yale University Press.* 285 pages. $6.00.

This eighth volume of the Science in Progress series contains articles based on recent Sigma Xi lectureships by 10 authors. Included are "The Origin and Evolution of the Universe," by G. Gamow; "Unsolved Problems of the Sun's Atmosphere," by Walter Orr Roberts; "The Earth's Atmosphere," by Joseph Kaplan; and "Microwave Spectroscopy," by Charles H. Townes.

Galileo's

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54 mm (2⅛")	330 mm (13").....	12.50
54 mm (2⅛")	390 mm (15.356")..	9.75
54 mm (2⅛")	508 mm (20").....	12.50
54 mm (2⅛")	600 mm (23½")...	12.50
78 mm (3 1/16")	381 mm (15").....	21.00
81 mm (3 3/16")	622 mm (24½")...	22.50
83 mm (3¼")	660 mm (26").....	28.00
83 mm (3¼")	711 mm (28").....	28.00
83 mm (3¼")	876 mm (34½")...	28.00
83 mm (3¼")	1016 mm (40")....	30.00
110 mm (4⅜")*	1069 mm (42 1/16")	60.00

*Not coated

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Gov't. Cost $200.

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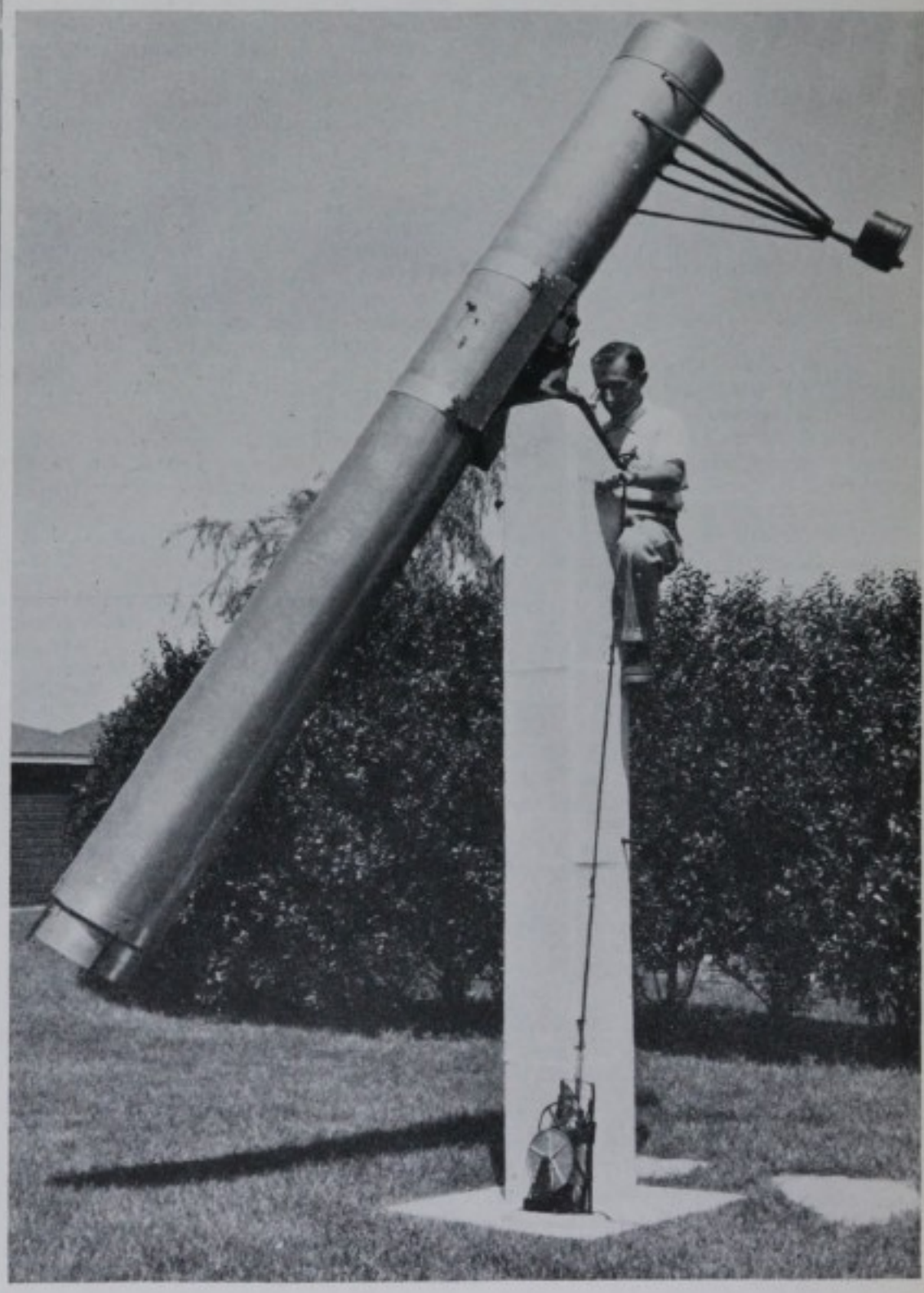
GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

A Large, Inexpensive Springfield Telescope

AFTER FINISHING my 6-inch reflector last year, I decided it would be too much work to make a large reflector of the Springfield type myself, and I planned to have such a telescope made to order. (This, I am sure, is considered by most ATM's as sheer treason.) A Springfield-mounted reflector works on the coude principle; the light from the primary mirror is reflected by a diagonal to a point just above the top of the polar axis, where there is another reflection to the eyepiece. There the observer always sits in one place, looking down the polar axis with the tube rotating around him.

The prices quoted were from $4,000 to $6,000 for a complete Springfield 12½-inch f/9 reflector including mounting, tube, controls, motor, and concrete pier. This amount of money was out of the question for me, and I decided to build the instrument myself. I purchased and read several excellent books about constructing telescopes, but in my case they did not help much. They gave complete instructions on how to build a Springfield mounting, but you had to have a lathe, plenty of machining experience, an array of machine tools, forms for casting, and casting experience. I had none of these.



A fixed observing position, regardless of the direction in the sky to which this 12½-inch reflector is pointed, makes using the large instrument easy for its builder, Max Collin, who is shown at the eyepiece. The driving mechanism is located at the base of the pier.

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All for $110.00 f.o.b. Amsterdam

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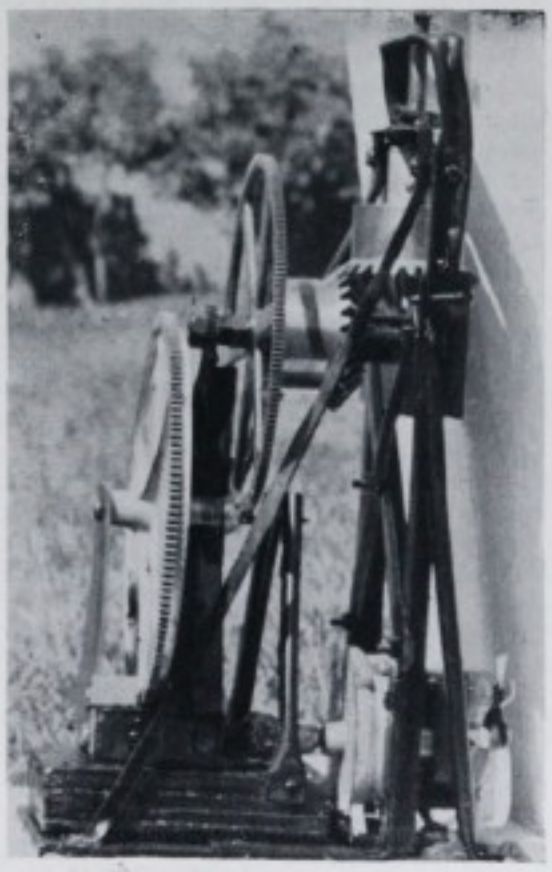
All I had was an electric drill and the usual tools one finds in a home—a hammer, saws, pliers, files, and the like. I looked at my 6-inch telescope again, but the farther away the 12½-inch seemed the more I wanted it.

Why not make it out of various parts that were originally designed for entirely different purposes? There must be thousands of parts for all kinds of machines; if the right ones could be found it would not take much work and money to put them together and make an efficient telescope. Of course, I was not interested in a makeshift affair; I wanted a scientific instrument.

I will not describe the making of the mirror, as it followed the conventional procedures outlined well in many books and articles. My own mirror experience is confined to one purchased and two made by me.

After the 12½-inch mirror was finished, I purchased a sheet of 12-gauge ¼" hard aluminum, 4' by 12', weighing 55 pounds and costing $33. It was obtained at a big steel company. I had the sheet rolled and welded into a tube 15½" in diameter and 12' long. This was the only outside labor on the whole job, for it was impossible for me to roll and weld such a big sheet of metal.

Aluminum, which some consider a poor material for a tube, was selected after due consideration for its advantages of light weight (one third as heavy as iron), nonrusting when left out of doors continually, and ease of working. The tube is 2½" larger in diameter than the mirror, and I extended the mirror 1" beyond the end of the tube into the open air, so the glass is always well ventilated. I have not found it necessary to line the tube with cork, although I might try it later just to see if there is any difference in seeing; I am sat-



An electric phonograph motor, visible at the lower right corner, drives the telescope through the spur and bevel gears, which are connected to the worm gear mounted on the polar axis.

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10"	1¾"	$19.00
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6"	1"	$ 5.50
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Precision Sleeve Type

Insure the efficiency of your telescope with this indispensable accessory for fine vernier focusing. The precise fit of all turned parts assures the optimum in focusing accuracy. Complete with built-in diagonal support. Eyepiece travel 2" to 5". Fits tubes from 4" to 8" O.D. and accommodates standard 1¼" eyepiece. Seamless brass throughout. Self centering on tube, one adjusting set screw for diagonal mirror. No special tools or jigs needed. **$5.00**

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Improved Hastings-Ross Formula. 1/5" (5 mm.) E.F.L. cemented triplet (solid) positive type. Highest light transmission through minimum glass thickness. Medium wide field, sharp to the very edge. Excellent color correction. Mounted in non-reflecting cap of fall-away type. O.D. 1¼". **Each $12.50**

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Twin-Achromatic Doublet about 1/3" E.F.L. (30x) made of two achromatic cemented doublets, of Bausch & Lomb manufacture. The field is sharp to the edge. Good color correction. In "French-doublet" screw type mounting, giving highest eyepoint possible with this short-focus combination. O. D. 1¼". **Each $8.00**

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isfied with the way it performs now.

After picking up the 12' tube and bringing it home securely tied to the top of my car, I placed it standing up in my yard and proudly admired its tremendous size and height. My wife came out of the house and told me to hide the monster at once in the garage or elsewhere. My 8-year-old son came running, his eyes lit up, "Gosh, what is it, a rocket ship, Dad?" One neighbor asked seriously if I intended to drill for oil.

Not discouraged, I hauled the tube into the basement, where it was painted with three coats of clear spar varnish on the outside and with three coats of blackboard coating on the inside. After trying four other flat paints and even the lacquer that is used to paint photographic equipment on the inside, I found that they all reflect light to a much higher degree than blackboard coating. As there was a long strip of aluminum left over from the original sheet, I put a collar on top and bottom of the tube for reinforcement and to improve its appearance.

The mirror cell, made out of leftover aluminum strips, consists of two separate parts. The cell was started by bending a draw-rod track (used for draperies) into a perfect circle. A 2" wide aluminum strip was attached with nuts and bolts. The same procedure was repeated for the second part of the cell that actually holds the glass, only this second part was made so it would fit into the bigger outside cell. To attach the mirror to the tube, four draw-rod tracks are screwed to the tube, with the cell sliding on eight nylon slides. All these parts can be purchased at any drapery store for 50 cents. There is never any stress on the mirror, and it can easily be taken indoors when observing is ended for the night; it is readily replaced in its proper position in a few seconds time. Alignment is by three wing screws mounted on the back of the cell.

For a counterweight I melted 80 pounds of lead on our electric cooking range. I recommend, however, that this not be done when one's wife has a dozen ladies over for a card party, which occurred on the evening I picked to melt the lead. To avoid drilling a hole through the lead weight, I put a piece of pipe into the fluid lead. After it had cooled, I peeled off the can in which it was melted the way one peels an orange and hammered the pipe out of the hole.

As shown in the picture, the weight was attached to the tube with drapery draw-rod track, and the support is so strong that I can hang my entire weight on the spot where the lead is and the supports will not move. One rod by itself bends easily, but arranged this way they have great strength. At first I had only four rod supports; for added safety I later added the two top side rods.

The Springfield mounting assembly was started by the purchase of a piece of 8" structural angle iron 1" thick. This re-

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NORTON'S "Star Atlas and Reference Handbook," latest edition 1950, $5.25; Elger's "Map of the Moon," $1.75; Davidson, "Astronomy for Everyman," $5.00; Lovell-Clegg, "Radio Astronomy," $4.00. All domestic and foreign publications. Write for list. Herbert A. Luft, 42-10 82nd St., Elmhurst 73, N.Y.

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METEORITES: Genuine visitors from space. 50c, $1.00, $2.00, $5.00, and $10.00 each. Atomiscope and radium disk shows atomic bombardment, "sparkling scintillation." $1.80. Laboratory, 2846 Oakley Ave., Baltimore 15, Md.

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quired two holes, one to carry a 1" bolt for the polar axis shaft, the other to take a short piece of 3" pipe to admit the pencil of light from the side of the tube. Drilling these two holes was the hardest job of the entire mounting; it took me one week in my spare time evenings. I wore out three drill bits making a series of small holes arranged one next to the other in a circle; then I sawed and filed the remaining thin walls between the holes.

The mounting picture shows this piece of angle iron held to the pier assembly by the 1" bolt, which has a square head. The assembly consists of a plate fastened to the pier, and above this a second plate (½" steel) that provides for exact latitude and horizontal adjustment. On this plate is the worm that runs a large 100-tooth ring gear, power being transmitted to it from the vertical shaft at the right by means of two bevel gears. Between the ring gear and the upper steel plate I put a 4" thrust ball bearing, and another is placed below the steel plate. By tightening the entire arrangement I can overcome the fault of ball bearings, namely, they move too easily.

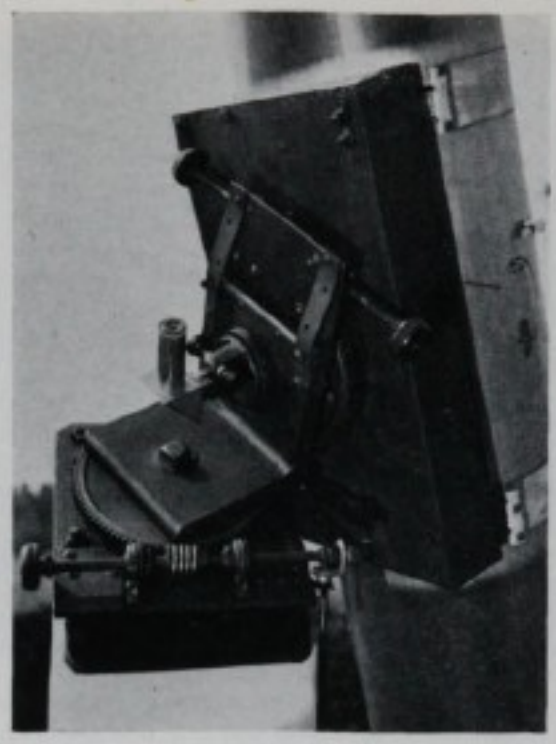
From the photograph it would appear that the tube can be moved in right ascension only by the worm control. This is not so, however, for on each corner of the under side of the angle iron I drilled a shallow hole into which I put small ball bearings. This permits the angle iron to rotate not only around the polar axis shaft but independently on the 100-tooth gear, moving on the embedded steel balls. Careful scrutiny of the gear just inside its periphery shows the tracks the steel balls have cut into the softer metal of the gear.

Thus, the tube can be moved without disturbing the electric drive just by applying a little pressure. This arrangement will come in handy when I later insert circles, as the driving mechanism can be set to maintain sidereal time throughout an evening's observing—the tube will be moved to a star's right ascension and declination directly.

In order to operate the right ascension slow motion by hand, the bevel gears that transmit the drive power can be disengaged by unlocking the small nut (with a rod handle) at the end of the rod carrying the worm gear. The control knobs for right ascension and declination slow motion are radiator knobs, but they serve their new purpose well. The focusing device was the only part purchased already made. The prism holder was made in two hours out of brass sheeting.

The photo on page 59 shows the driving mechanism, which is set at the foot of the pier. The electric phonograph motor is stepped down with several gears, and the connecting shaft between the driving mechanism and the top of the pier is made of ⅜" brass rod. Everything has three coats of black paint, and all gears are coated with waterproof car water-pump grease. During the day, a plastic cover protects the top of the tube and the mounting.

The pier was constructed by digging a hole 3' by 3' by 4' deep, funnel shaped toward the bottom so that frost could not heave the telescope out of line. Into this hole I put chimney liners 12" by 12" to a height of 100". Four brass rods were put throughout the entire height and depth of the pier, and the inside was filled with poured concrete.



The eyepiece is mounted at the intersection of the polar and declination axes; it remains stationary while the telescope is moved around the bolt, which locates the polar axis, and the focusing device, which locates the declination axis.

To reach the observing perch, which is a bicycle seat, I use the same method as the telephone company, removable spikes that extend out of the pier. When the Springfield instrument is not in use, these are removed to keep unauthorized persons from ascending.

This is a list of my expenditures:

Entire Springfield mounting	$72.80
Tube and weight, including rolling and welding	78.30
Mirror cell	4.50
Motor drive	15.10
Concrete pier	36.50
Rack and pinion, spider	18.25
Mirror, oval diagonal, prism, three eyepieces	200.00
	$425.45

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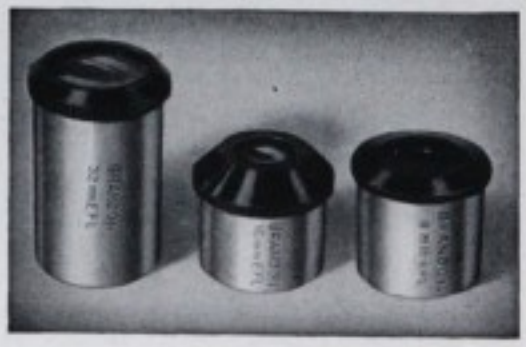

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Universal time is used unless otherwise noted.

THE MARS-VENUS CONJUNCTION OF OCTOBER 4, 1953

AN UNUSUALLY close conjunction of Mars and Venus occurred on the morning of October 4th, when Venus passed only two minutes of arc south of the more slowly moving Mars. Closest approach took place at 1 a.m. EST, when the two planets were still below the horizon. At 5 a.m., I observed Mars and Venus visually with 7 x 56 binoculars, and photographically with an f/7.7 Dallmeyer telephoto lens of 17 inches focal length. Two photographs of the planets were taken with exposures of one and five seconds. Finopan film was selected for its fine grain and panchromatic quality, rather than the faster but less fine-grained ultra-speed film. On the five-second exposure both planets are slightly trailed, indicating that a 17-inch focal length camera should be guided for exposures longer than one second. This trailed picture is useful in distinguishing the planets from possible photographic defects.

The apparent distance between the planets was measured directly from the negatives with a 14x traveling microscope. The microscope was carried over the illuminated stationary negative by a very fine screw, whose turns could be counted. This was adapted from an old dictaphone. On a photograph of the moon taken at the same time, its diameter of 30 minutes of arc was found to correspond to 368 turns, giving the scale of the negatives. The distance between Mars and Venus was 80 turns, or 6.5 minutes of arc. This agrees very well with their actual separation at five o'clock, which was 6.4 minutes, according to data in the **Nautical Almanac.**

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METEORS IN DECEMBER

The second best annual display of meteors, the Geminid stream, is at maximum on December 12th. Rates of 30 meteors per hour are usual under favorable conditions, but over 60 per hour have been reported on very good occasions. The moon, nearing the first-quarter phase, may interfere slightly; however, Geminids may be seen a week before and after maximum. Typical meteors of this shower are of medium speed, white, some bright and trained. The radiant is near the star Castor.

The December Ursids attain maximum on December 22nd, shortly after full moon, with predicted rates of 12 per hour. One of our readers, John Paul Bay, points out that this may be the same shower as the Kappa Draconids described 30 years ago by W. T. Olcott.

E. O.

OCCULTATION PREDICTIONS

December 17-18 **23 Tauri** 4.2, 3:43.5 +23-48.2, 12, Im: **G** 10:50.0 —1.0 +0.6 29; **H** 10:51.9 —0.5 —1.0 86; **I** 10:41.6 —0.9 —0.1 47.

December 17-18 **Eta Tauri** 3.0, 3:44.7 +23-57.7, 12, Im: **H** 11:26.8 —0.6 0.0 53.

December 17-18 **27 Tauri m** 3.8, 3:46.4 +23-54.7, 12, Im: **H** 12:03.2 —0.2 —0.5 68; **I** 12:01.1 —1.0 +0.9 25.

December 17-18 **28 Tauri** 5.2, 3:46.4 +23-59.7, 12, Im: **H** 12:08.8 —0.5 +0.1 47.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

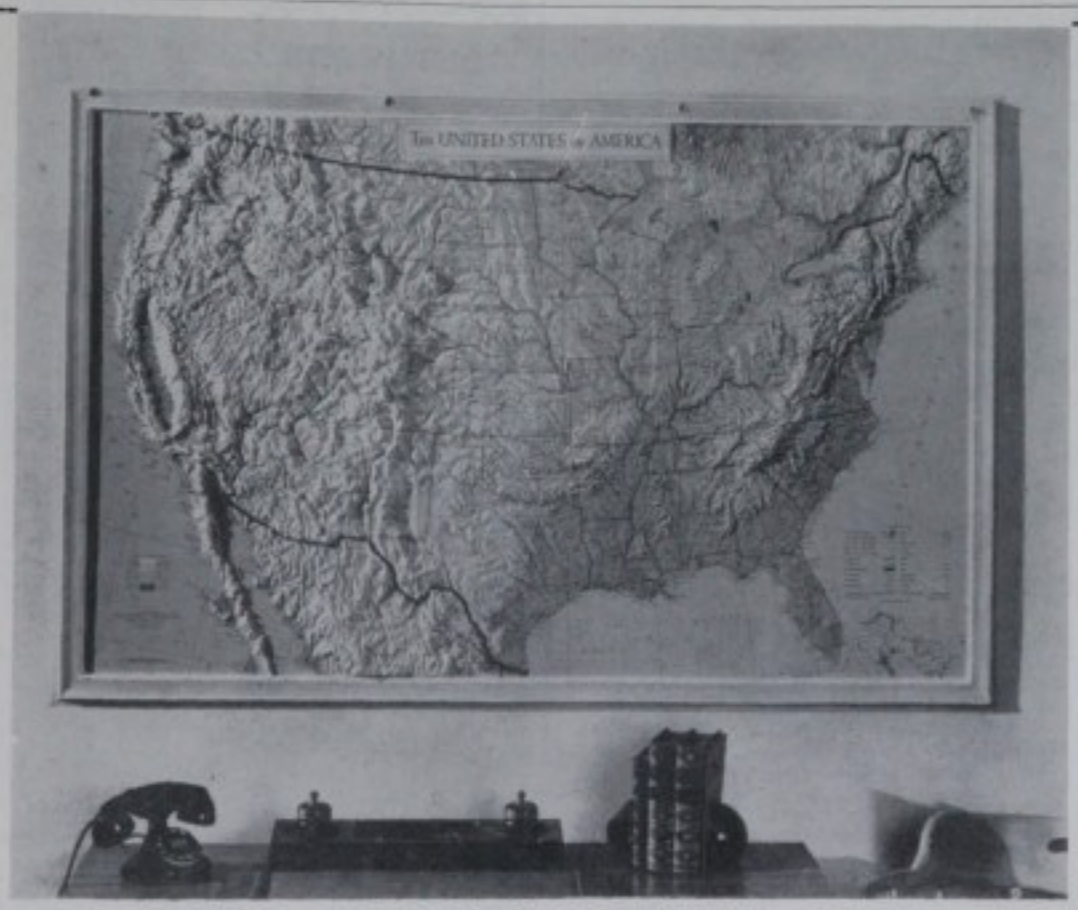
The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.6	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	+114°.0,	+50°.9
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.



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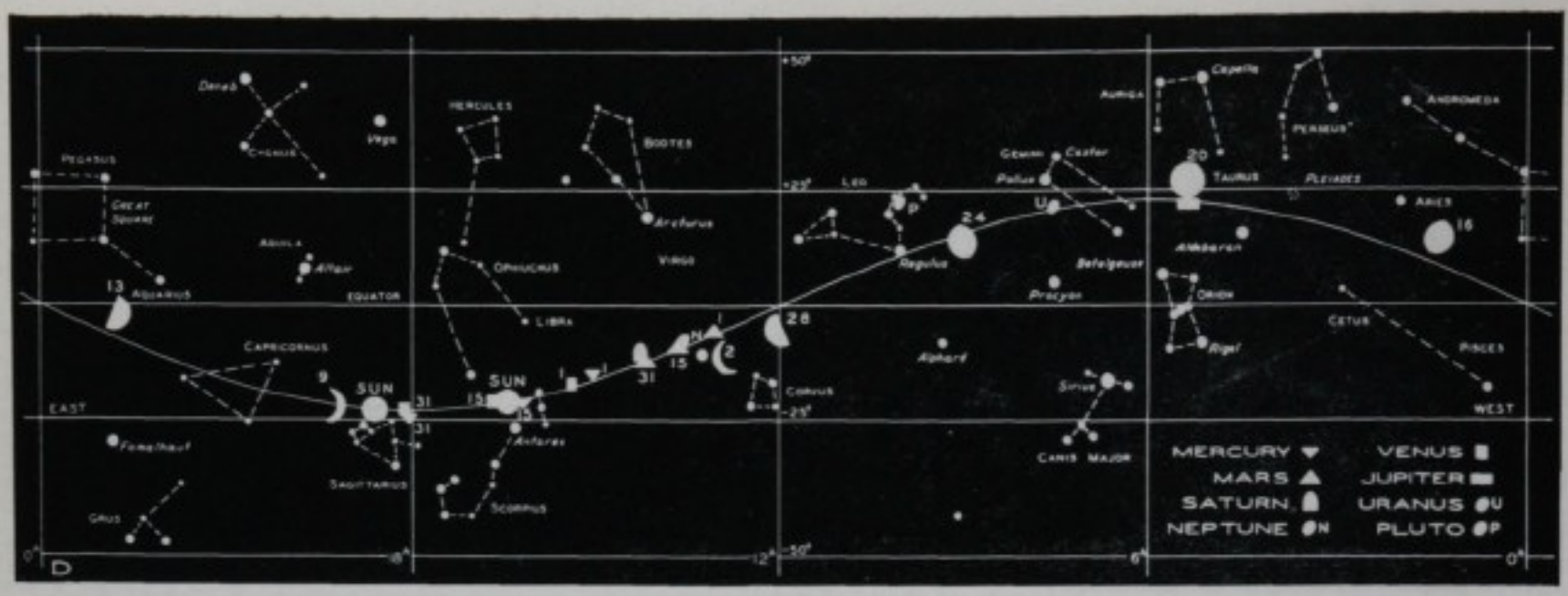

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury attains greatest elongation on December 1st, 20° 21′ west of the sun, when it is of magnitude −0.3 and rises 1¼ hours before the sun. The planet may be viewed in the morning sky for the following two weeks.

Venus will disappear into the sun's glare in the morning sky of late December. However, on the 10th it may still be seen rising one hour before the sun; it is of magnitude −3.4. Telescopically, Venus will appear almost circular with 98% of the disk illuminated, and it is 10″ in diameter at that time.

Earth arrives at heliocentric longitude 90° on December 22nd at 3:23 Universal time. Winter commences in the Northern Hemisphere and summer in the Southern.

Mars, at magnitude +1.7, is traveling through eastern Virgo, where it rises 4½ hours before the sun in the middle of the month. On the 13th, at 8^h UT, Mars will pass 29′ south of Neptune.

Jupiter reaches opposition to the sun on December 13th, about 390 million miles from the earth. It will be of magnitude −2.3, and excellently placed for observation in northern latitudes, visible through the night. Jupiter is in retrograde motion in eastern Taurus, presenting a disk 48″ in diameter, which is discernible in binoculars; several of the brightest moons may also be seen with such optical aid whenever they are sufficiently far away from the planet.

Saturn may be seen closely following Mars in the morning sky. The planet crosses into Libra in late December, moving eastward among the stars. The ring system now presents its northern face, inclined 18° to our line of sight in mid-month.

Uranus can be observed most of the night, about 3° south and slightly west of Kappa Geminorum. The planet is of the 6th magnitude, and is in retrograde motion.

Neptune, near Mars in mid-month, may be viewed during the early morning hours with the aid of binoculars. It is just west of 82 Virginis, and is at the 8th magnitude.

E. O.

VARIABLE STAR MAXIMA

December 13, R Canum Venaticorum, 134440, 7.7; 15, S Pegasi, 231508, 8.0; 18, R Sagittarii, 191019, 7.2; 20, S Sculptoris, 001032, 6.8; 21, Z Ursae Majoris, 115158, 6.6; 23, R Ursae Majoris, 103769, 7.6; 23, RV Sagittarii, 182133, 7.8; 25, T Centauri, 133633, 6.1; 30, R Reticuli, 043263, 7.7.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

DEEP-SKY WONDERS

THE ASSUMPTION that the modern stargazer does not enjoy as transparent skies as did the ancients is probably pretty much a myth. For, except in our modern industrial areas, there is no evidence that our atmosphere has deteriorated. Indeed, one major volcanic explosion may put more obscuring dust into the whole atmosphere than all our industrial chimneys together.

Suggestive of these conclusions is the fact that so few of the fainter objects, readily seen today, are commented on by Hellenistic astronomers. M13, M5, the Orion nebula, and another dozen or so naked-eye objects are absent from ancient reports. Uranus, at times of magnitude 5.5, is then easily seen, but it was unrecognized before Herschel. In good air in the United States, 7th-magnitude stars can be seen sometimes, but the old catalogues stop at the 6th magnitude.

The Double Cluster (h and Chi Persei) was about as faint a nonstellar object as Ptolemy mentioned, and he seems the first to include it. Although it is conspicuous to modern stargazers, we find it but briefly mentioned in the Alphonsine Tables and some other old works. Today, we list the cluster as NGC 869 and 884, centered at 2^h 18^m.8, +56° 54′ (1950). Diameters of 36′ make each component

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cluster conspicuous, but Shapley lists 13 open clusters of larger size; one, IC 2602, is 70′ in diameter. The combined visual magnitude is 4.5, and with its rather open structure the Double Cluster makes a most magnificent field for anything from opera glasses to medium-sized telescopes. Indeed, it takes a pretty foggy night to dim it out, and it is an old standby for public nights when objects suitable for the novice are scarce.

WALTER SCOTT HOUSTON

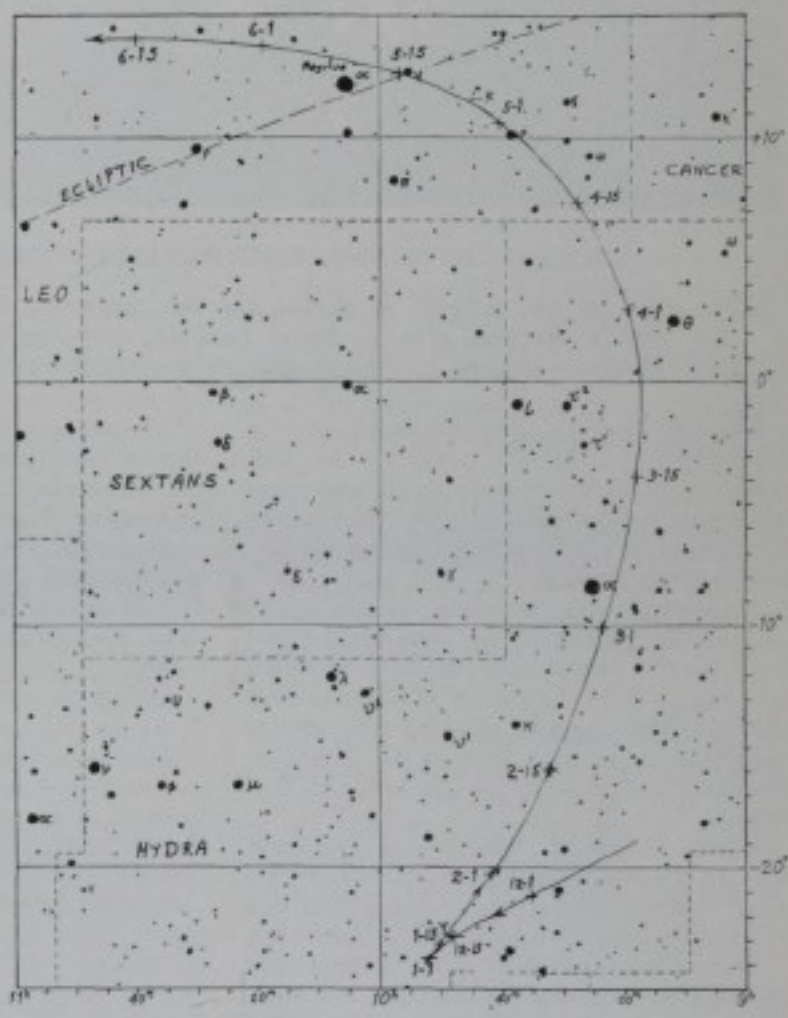
MOON PHASES AND DISTANCE

New moon	December	6, 10:48
First quarter	December	13, 16:30
Full moon	December	20, 11:43
Last quarter	December	28, 5:43
New moon	January	5, 2:21

	December		Distance	Diameter
Perigee	16,	14ʰ	228,700 mi.	32′ 28″
Apogee	28,	15ʰ	251,300 mi.	29′ 33″
	January			
Perigee	10,	10ʰ	229,800 mi.	32′ 19″

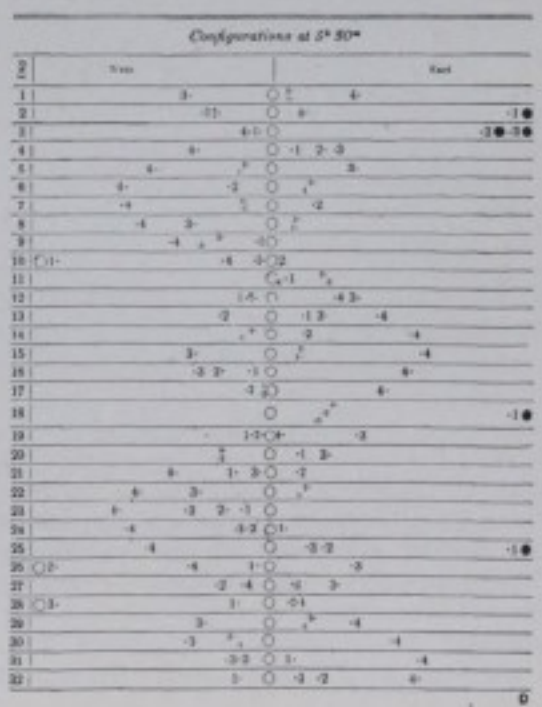
PATH OF PALLAS

This chart shows the path of Pallas, Asteroid 2, from December 1, 1953, to June 15, 1954. It will brighten from magnitude 7.3 in December to 6.7 at opposition on February 13th, and then fade to 8.2 in June. The chart is a tracing by Edward Oravec from the Skalnate Pleso atlas, to show stars brighter than magnitude 7.75. On May 4th, when at magnitude 7.5, Pallas will pass 30′ south of the long-period variable R Leonis. The AAVSO "a" field chart of that star shows comparison stars for estimating the brightness of Pallas in April and May.



JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below for the Universal time given. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the **American Ephemeris and Nautical Almanac.**



MINIMA OF ALGOL

December 2, 14:55; 5, 11:44; 8, 8:33; 11, 5:22; 14, 2:11; 16, 23:00; 19, 19:49; 22, 16:38; 25, 13:28; 28, 10:17; 31, 7:06.

These minima predictions for Algol are taken from the 1953 **Handbook** of the Royal Astronomical Society of Canada.

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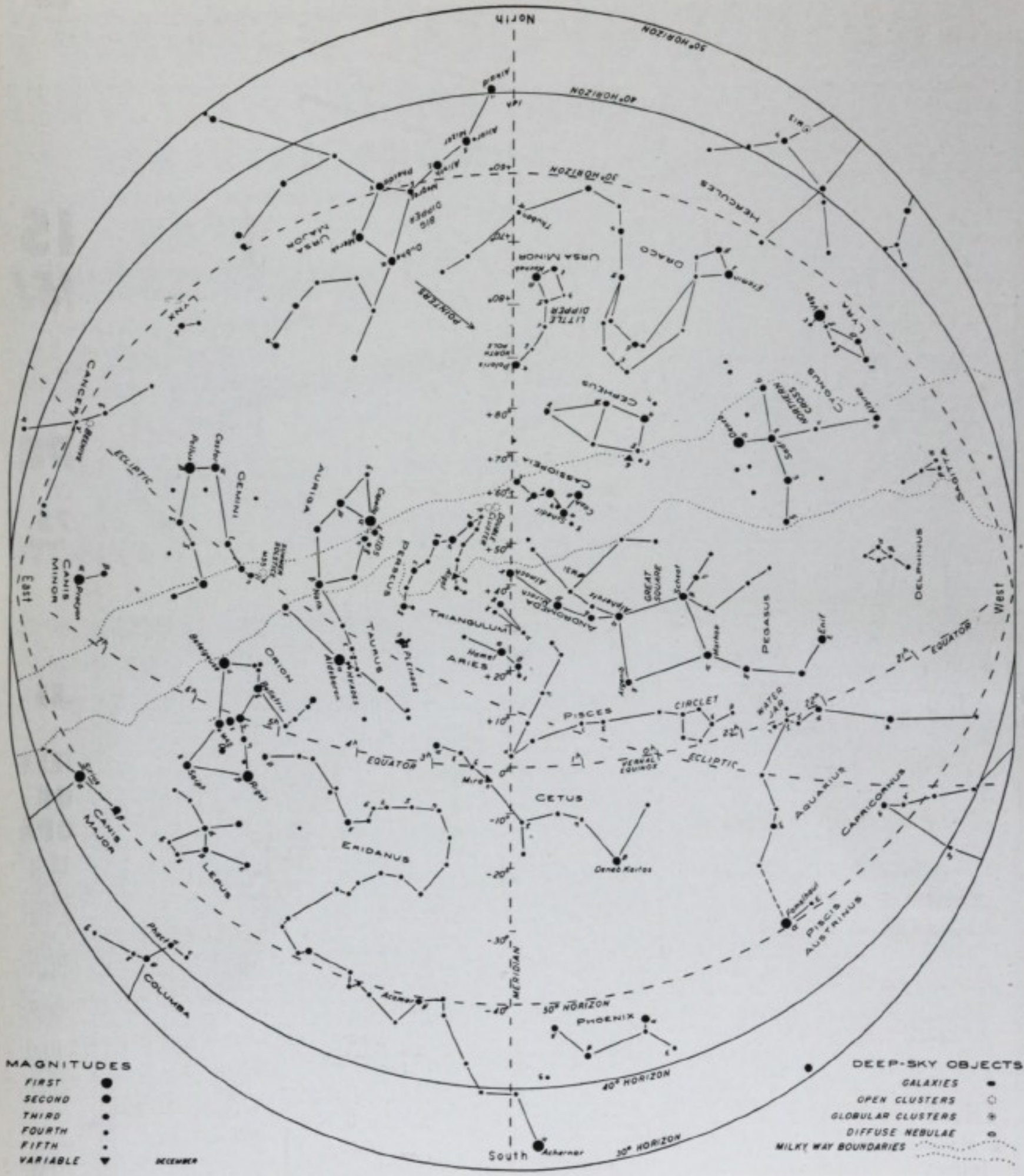

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of December, respectively.

STARS FOR DECEMBER

DURING December evenings the Milky Way is unusually well placed for view, as a tattered band of light, spangled with stars, that stretches from the eastern horizon to the western, passing nearly overhead. Among the most beautiful of the constellations in the Milky Way is Cassiopeia, now visible as an M-shaped group of stars, high in the northern sky. Next to it in the northeast is Perseus, marked by a long curving line of stars that extends southward toward the Pleiades.

Beta (β) Persei is of particular interest, for it is the famous variable star Algol. At regular intervals of slightly less than three days it fades temporarily, when it suffers partial eclipse by its large dark companion star. Normally it is about as bright as Gamma (γ) Andromedae, but at minimum light Algol is more a match for the 3½-magnitude star just south of it. After one has learned to recognize Algol, it is interesting to look for it at the predicted times of minimum light listed on the Observer's Page. Algol's loss of light will be conspicuous within an hour before or after the predicted time.

High in the southwest is the Great Square of Pegasus, formed of four stars of about the 2nd magnitude, one of which actually belongs to the neighboring constellation Andromeda. Scheat in the Great Square is one of the largest known stars.

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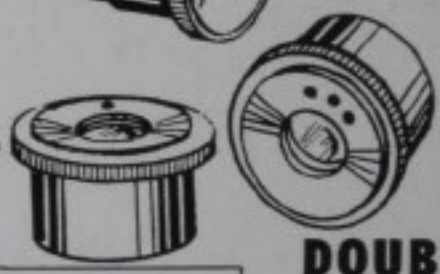

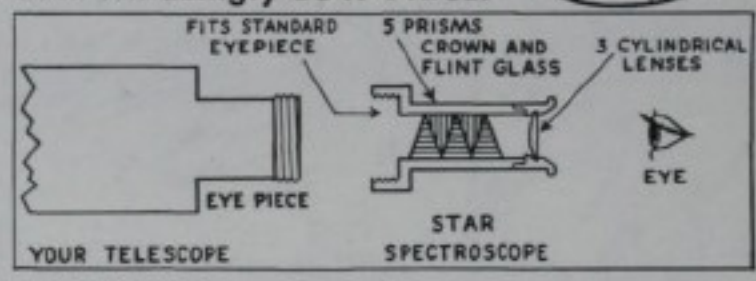

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The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of March, respectively.

SOUTHERN STARS

DURING March evenings the southern observer will find Crux, the Southern Cross, well up in the southeastern sky. This constellation is a fairly recent one, as until the 17th century the stars forming it were assigned to the hind feet of the Centaur, following Ptolemy.

In this group is one of the most remarkable objects in the heavens, the Coalsack, which appears as a large dark hole in the Milky Way. It is an enormous cloud of interstellar dust, detectable because it blots out the light of the stars behind it. The Coalsack was familiar to the Portuguese navigators who, in their voyages of exploration more than four centuries ago, were the first Europeans to view the constellations around the south celestial pole.

About one degree southeast of Beta Crucis is the open star cluster Kappa Crucis, which is a fine sight in field glasses or small telescopes.

Near the meridian is another famous cluster, Praesepe or the Beehive, in Cancer. It is visible to the unaided eye as a hazy-looking 4th-magnitude object. Although it is one of the very few clusters recorded by the ancient astronomers, Praesepe was not clearly recognized to be made up of stars until after the invention of the telescope.

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